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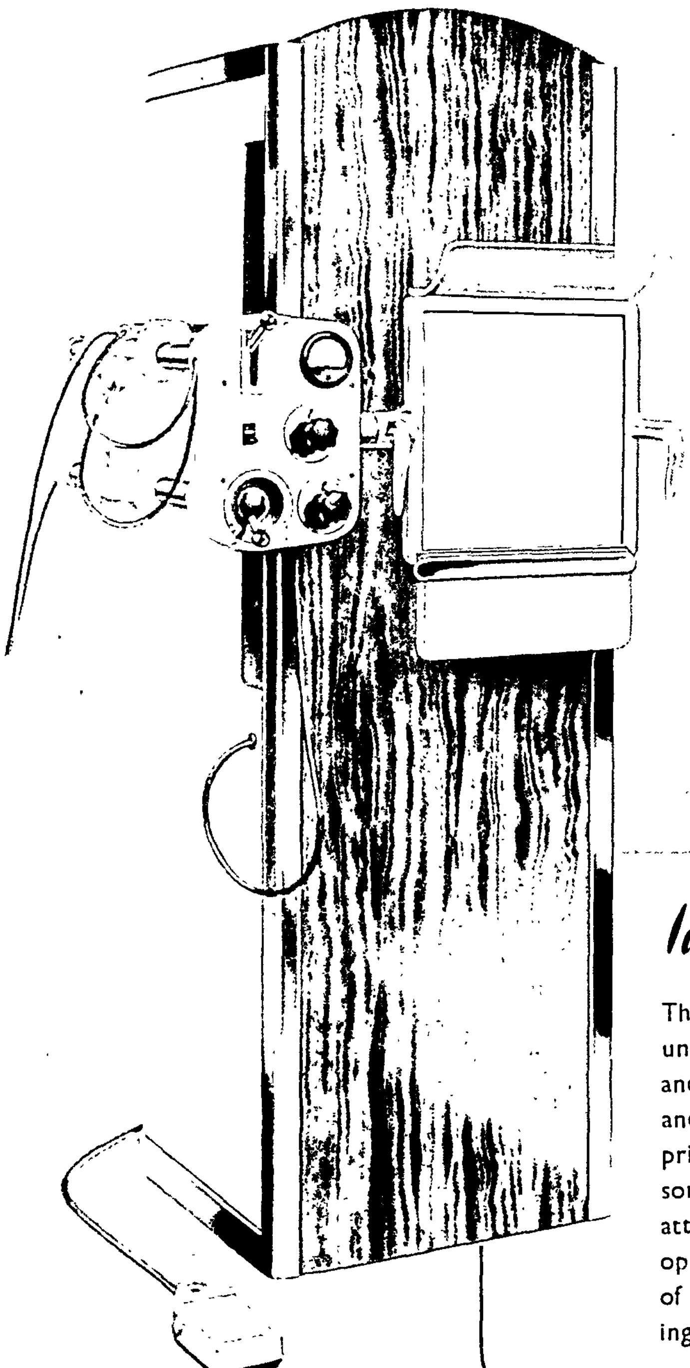


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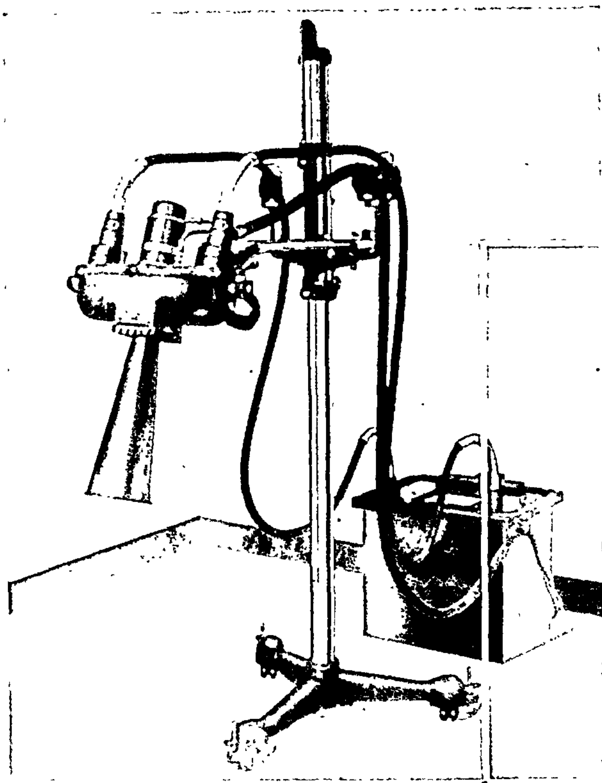

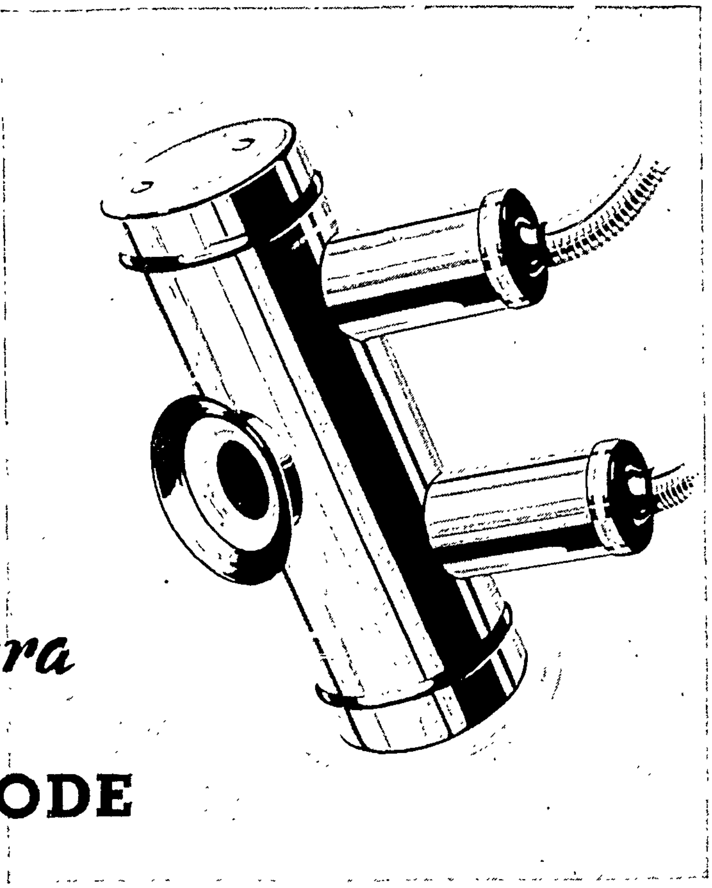

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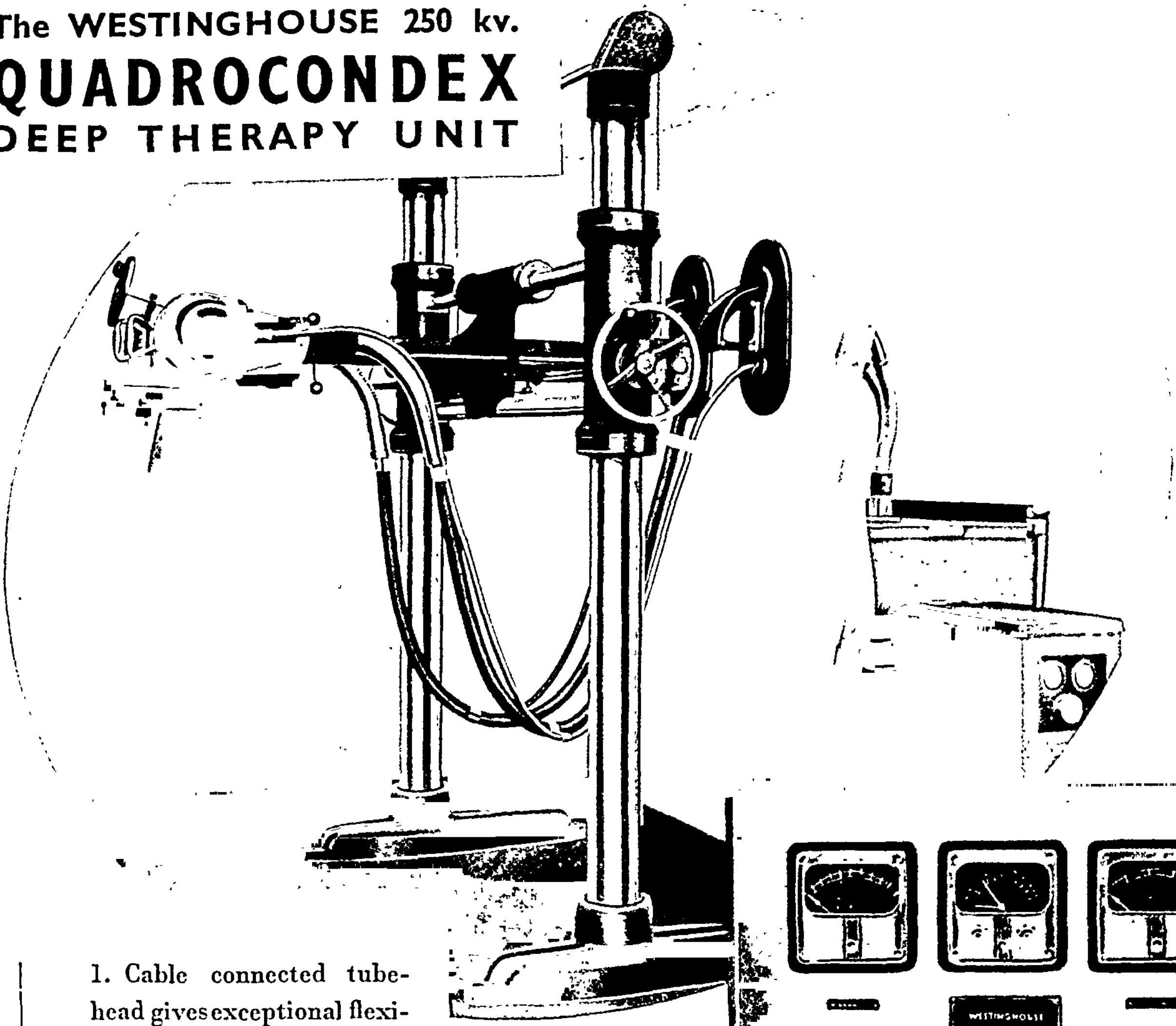

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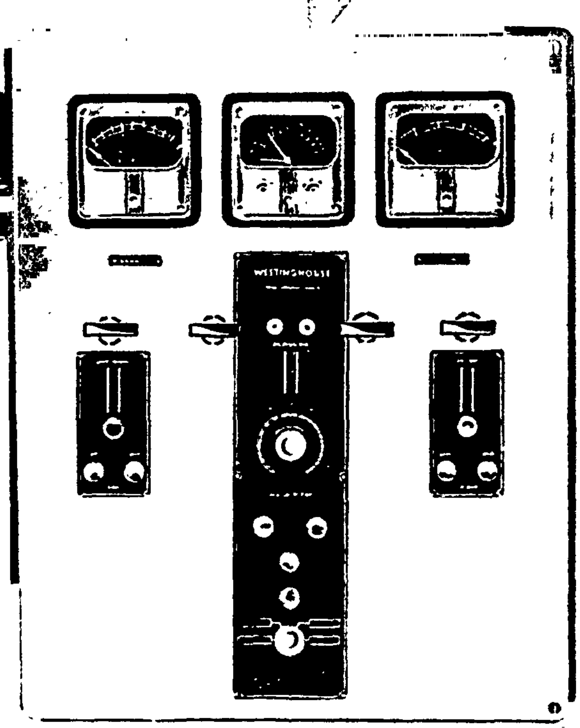

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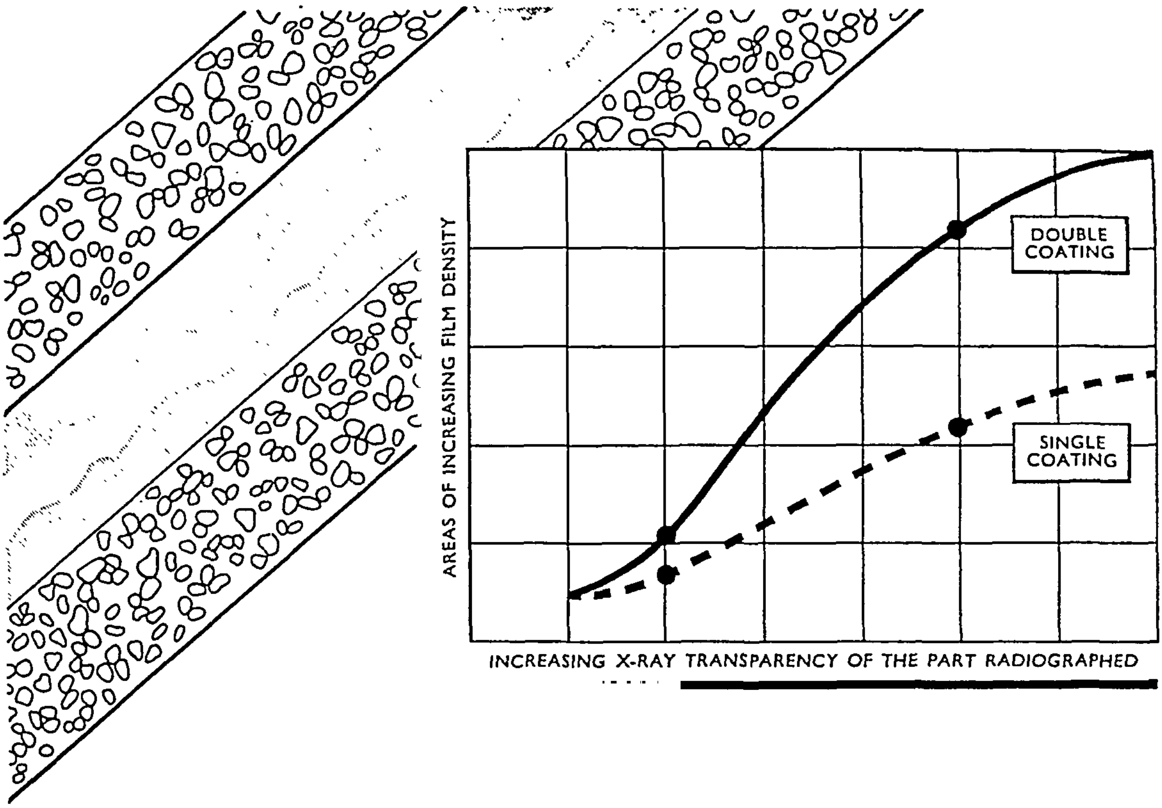
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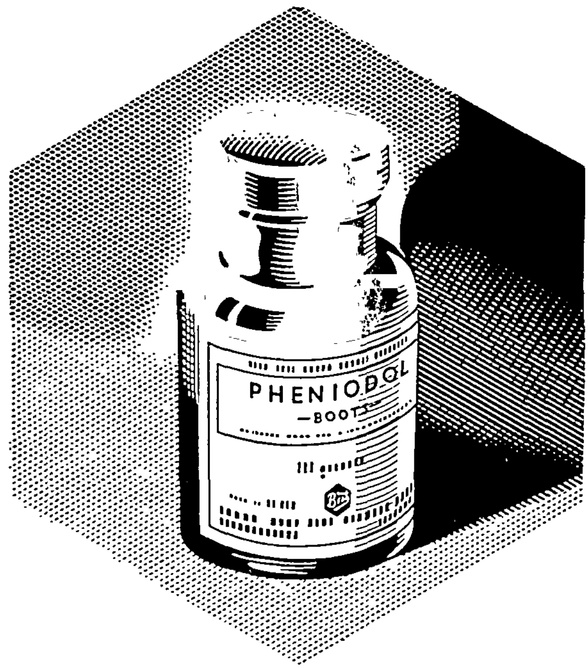

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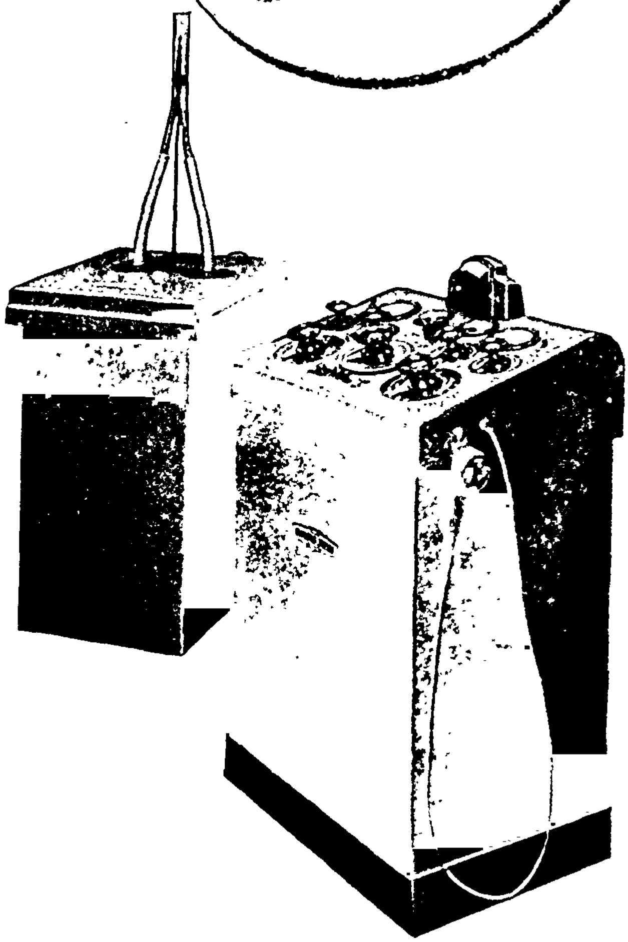

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THE EFFECT OF BETA RAYS ON CELLS CULTIVATED *in vitro*

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INTRODUCTION

THE effect on living matter of γ rays, X rays and, to a certain extent, neutrons, has been investigated by many observers on various materials of different complexity. The biological action of pure β rays is not so well known, however, and when opportunity presented us with such a source of radiation it was decided to study their effect on a relatively simple tissue of the type already used for studying the biological effects of several different types of ionizing radiation.

It was not expected that the biological response would differ widely from that seen after exposure to X rays, since the secondary β radiation produced by the passage of penetrating rays through matter is almost certainly an intermediate agency by which biological changes are brought about.

MATERIAL AND METHODS

1. *The beta ray source and the physical measurement of beta ray dosage*

The source of β radiation was three discs of uranium UX 1, manufactured by Imperial Chemical Industries and kindly provided by Dr. E. Brettscher, then of the Cavendish Laboratory, Cambridge, working in collaboration with Dr. B. B. Cook and Dr. G. Martin.

It was first necessary to determine the physical dosage of β radiation in röntgens* before proceeding to the biological experiments, so that the relative efficiency of β rays and of X or γ rays could be compared. The estimate obtained of the dose-rate received by the tissue cultures is probably reliable to ± 10 per cent. The three sources available were unfortunately not of equal strength.

The ionization chamber used was in the form of a shallow box, 1·92 cm. square and 0·52 cm. deep. The top and bottom of the chamber and the central collecting electrode were of aluminium foil (2·37 mgm./cm.^{2} superficial mass) so that the β rays passed through the chamber with little scattering. A lead diaphragm on the top of the chamber was used to limit the width of the pencil of β rays, the diameter of the aperture being 0·64 cm. except where stated otherwise. The dose-rate at the position of the diaphragm was q/Aht, where q is the charge in electrostatic units collected in time t, A is the area of the aperture, and h is the thickness of the chamber.

The following measurements were made:

(*a*) *Variation of diameter of aperture*

To verify that the estimate of the dose-rate was independent of the area of the aperture, two sizes of aperture were used, with the following results (source at 3 cm.):

TABLE I

Diameter of aperture (cm.)	Depth of chamber (cm.)	Effective volume (cm.^{3})	e.s.u. per second	e.s.u. per sec. per cm.^{3}
0·64	0·52	0·1673	0·1188	0·710
0·96	0·52	0·3764	0·2686	0·714

* 1 röntgen being the dose of radiation liberating ions carrying 1 e.s.u. of charge of either sign per 0·001293 gm. of air.

(*b*) *Variation of dose-rate with distance between source and chamber*

The distance was measured from the top surface of the chamber to the nearest point of the source. The dose-rates at different distances were:

TABLE II

Distance d (cm.)	Dose-rate I (e.s.u./sec.)	$I(d+0{\cdot}3)^{-2}$
1·15	0·629	1·32
2·15	0·2166	1·30
3·15	0·1136	1·35
4·15	0·0672	1·33

It is seen that over the range of distances 1–4 cm. the dose-rate at distance d from the source is proportional to $(d+0{\cdot}3)^{-2}$. This formula is used as an interpolation formula to calculate the dose-rate at intermediate distances.

(*c*) *Absorption in tissue-like material*

Sheets of paper or cardboard were laid on the top of the chamber to determine the diminution of dose-rate due to intervening tissue. The results obtained from source 1 are shown in Fig. 1, which gives the

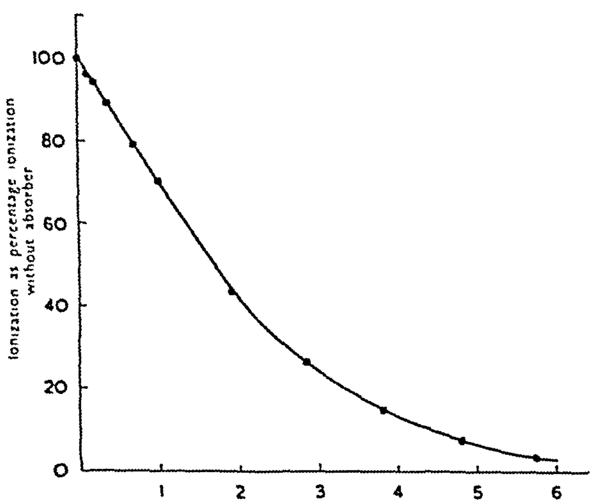

Fig. 1.
Graph showing absorption of uranium UX 1 beta rays in tissue-like material.

percentage depth-dose at distances of from 1 to 6 mm. below the surface of tissue-like material of density 1·0 gm. cm.^{3}, compared with the dose-rate at the same point in the absence of absorber taken as 100 per cent.

(*d*) *Back scatter*

When the ionization chamber was used without restricting aperture, it was determined that a block of wood immediately below the chamber increased the dose-rate by 5 per cent. as a result of scattering back the β rays.

The dose-rate received by the cells of a tissue culture was calculated from the ionization measurements made, as described above, on the assumption that the cells concerned were about 80 μ below the inner surface of the cover slip.

2. *Tissue culture technique*

The tissue used for the experiments was obtained from the choroid and sclerotic of 9–11-day chick embryos. The explants were grown on glass cover slips in a medium of fowl plasma and embryo extract by the hanging drop technique, and were transplanted every 48 hours. Cultures for irradiation were selected 24 hours after the second subcultivation by examination on a warm-stage microscope. Each culture was paired with another, judged to be of approximately equal mitotic activity, and for every experimental observation not less than five such pairs were used, one culture of each pair being irradiated while the other served as its control. Cultures were fixed in Susa solution and stained with Ehrlich's hæmatoxylin.

3. *Irradiation*

The dose of radiation was 1000 r. The dose-rate used varied according to the strength of the β-ray source and the available values were 224 r/min., 200 r/min. and 74 r/min. The cultures were exposed singly in a hot box kept at 37°C. and after irradiation were either fixed at once or returned to the incubator for periods up to 24 hours. With the dose-rate of 200 r/min., cultures were fixed immediately after exposure and at 9 and 24 hours after irradiation; at 224 r/min. they were fixed 80 minutes, 5 hours and 18 hours after exposure; and with the dose-rate of 74 r/min. they were fixed 30 minutes and 15 hours after exposure. (See Table III, cols. A and H.)

4. *Assessment of biological effects*

All the dividing cells in each culture (irradiated and control), except those in and immediately around the central explant, were counted and the mitotic counts in the irradiated cultures expressed as a percentage of the control counts. *Abnormal mitotic figures* were included in the total mitotic count, but were also recorded as a percentage of the total mitotic count.

Degenerate cells were enumerated by selecting 4–6 fields in each culture and counting all the degenerate and resting cells present. The result was expressed as the number of degenerate cells per hundred resting cells.

The percentage of abnormal mitotic figures in control cultures where they occasionally occurred was subtracted from that in the corresponding irradiated culture before plotting the point on the graph; similarly the percentage of degenerate cells seen in control cultures was subtracted from that in the corresponding exposed cultures before the count was plotted.

Results

Table III (cols. B, D, F and H) and Fig. 2 show the sequence of events for a period of 24 hours following an exposure to 1000 r of β rays.

Mitosis. There is a slight drop in mitotic activity by the end of the exposure. The greatest fall, however, occurs 30 and 80 minutes after irradiation (counts 15 per cent. and 4 per cent. respectively of that of the controls). A slight increase in the number

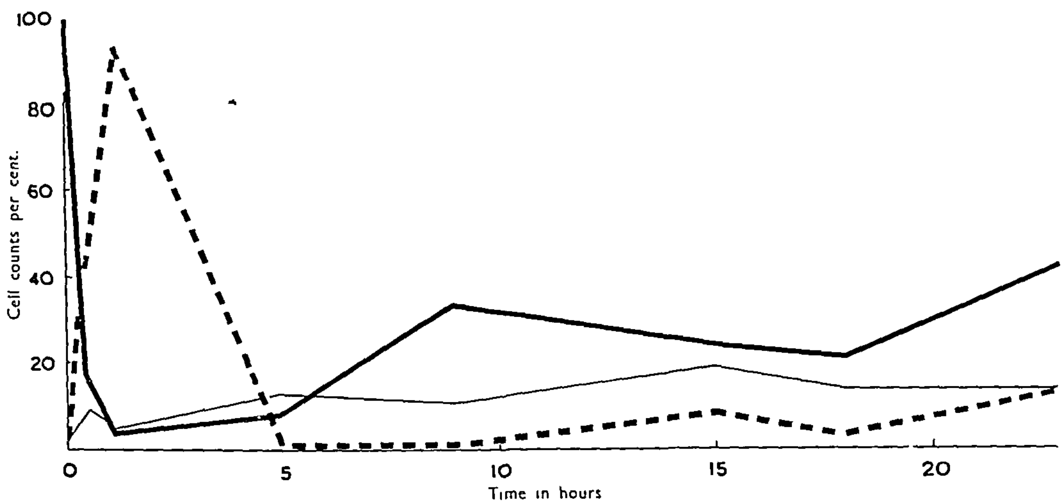

Fig. 2.

Graph showing reduction in mitosis and occurrence of abnormal mitosis and cell degeneration in tissue cultures of avian fibroblasts exposed to 1000 r of *beta* rays. —— Mitosis. --- Abnormal mitosis. —— Cell degeneration.

TABLE III

Comparison of Results Obtained after an Exposure to 1000 r of β and X Rays

Time After Exposure	Percentage Reduction of Mitosis		Abnormal Mitosis Per Cent. of Total Mitotic Count		Number of Degenerate Cells per Hundred Resting Cells		Dose-rates Used	
	β rays	X rays	β rays	X rays	β rays	X rays	β rays	X rays
A	B	C	D	E	F	G	H	I
Immediately	$87 \pm 7\cdot9$		$3 \pm 1\cdot7$		$3 \pm 1\cdot1$		200 r/min.	
30 minutes	$15 \pm 2\cdot9$	$36 \pm 3\cdot3$	$55 \pm 3\cdot8$	$39 \pm 3\cdot0$	$9 \pm 2\cdot6$	$0 \pm 1\cdot0$	74 r/min.	100 r/min.
80 minutes	$4 \pm 0\cdot4$	$13 \pm 2\cdot9$	$93 \pm 2\cdot9$	$53 \pm 2\cdot9$	$5 \pm 1\cdot3$	$6 \pm 2\cdot2$	224 r/min.	100 r/min.
5 hours	$8 \pm 4\cdot5$	0	$0 \pm 2\cdot4$	0	$13 \pm 2\cdot4$	$11 \pm 3\cdot3$	224 r/min.	100 r/min.
9 hours	$34 \pm 6\cdot2$	$30 \pm 8\cdot2$	0 ± 1	$3 \pm 2\cdot0$	$11 \pm 2\cdot5$	$16 \pm 5\cdot6$	200 r/min.	100 r/min.
15 hours	$25 \pm 6\cdot3$	$27 \pm 4\cdot8$	$9 \pm 3\cdot3$	$6 \pm 3\cdot6$	$19 \pm 3\cdot3$	$17 \pm 3\cdot8$	74 r/min.	100 r/min.
18 hours	$22 \pm 3\cdot8$		$4 \pm 2\cdot6$		$14 \pm 2\cdot1$		224 r/min.	
24 hours	$43 \pm 5\cdot6$	$7 \pm 3\cdot1$	$14 \pm 3\cdot3$	$14 \pm 4\cdot6$	$14 \pm 3\cdot4$	$21 \pm 1\cdot0$	200 r/min.	100 r/min.

of cell divisions at 5 hours marks the beginning of mitotic recovery which reaches 30 per cent. of the normal at 9 hours and, after a further slight depression, nearly half the control value at 24 hours.

Abnormal mitosis. At 30 minutes after exposure more than half the number of dividing cells, and at 80 minutes practically all of them are abnormal. The disturbance in cell division is mainly confined to meta- and anaphase. Fragmentation of chromosomes with lag in division, fusion and clumping of chromosomes and formation of chromosome bridges during movement towards the spindle poles could be observed. In some cases cells fail to divide after the division of the chromosomes and show a considerable enlargement instead. There are no abnormal mitotic figures 5 and 9 hours after exposure, but they reappear within 15 hours and persist up to 24 hours.

Degenerate cells are observed shortly after irradiation. These are cells damaged by radiation in which certain nuclear and cytoplasmic changes lead to the death of the cells. A separation of the chromatic from the non-chromatic material can be observed. Chromatine granules make their appearance and coalesce into a mass deeply staining with hæmatoxylin, which gradually breaks up and is dissolved. These nuclear changes are accompanied by the break-up of the cytoplasm. The number of degenerate cells rises gradually to a peak value of 19 per cent. of the resting cell count at 15 hours and remains constant for the rest of the observation period.

Comparison of beta-ray experiments with previous work with X rays

Table III and Fig. 3 summarize the results of similar experiments made with X rays (1000 r delivered at 100 r/min.) (Lasnitzki, 1943).

A comparison of the two sets of figures suggests that the effects of β rays and X rays are *qualitatively* similar. Both radiations are followed by inhibition of mitosis, production of abnormal mitotic and degenerate cells. Planimetric measurements of the surface area bounded by mitosis and degeneration in Figs. 2 and 3 show that these are of the same order in both experiments. The results in arbitrary units are:

Mitosis:	β rays	830
	X rays	642
Degeneration:	β rays	468
	X rays	510

Some significant quantitative differences appear, however, at the beginning and at the end of the observation period. β radiation causes a greater damage shortly after irradiation in contrast to X rays: the fall in mitosis is more marked and the number of abnormal mitotic figures and degenerate cells higher after β radiation. On the other hand, β-irradiated cultures show partial recovery of mitosis (43 per cent. of normal) at 24 hours after exposure, while those treated with X rays show much less mitotic activity at this time (7 per cent. of normal) and do not reach a similar state of recovery until six days after irradiation.

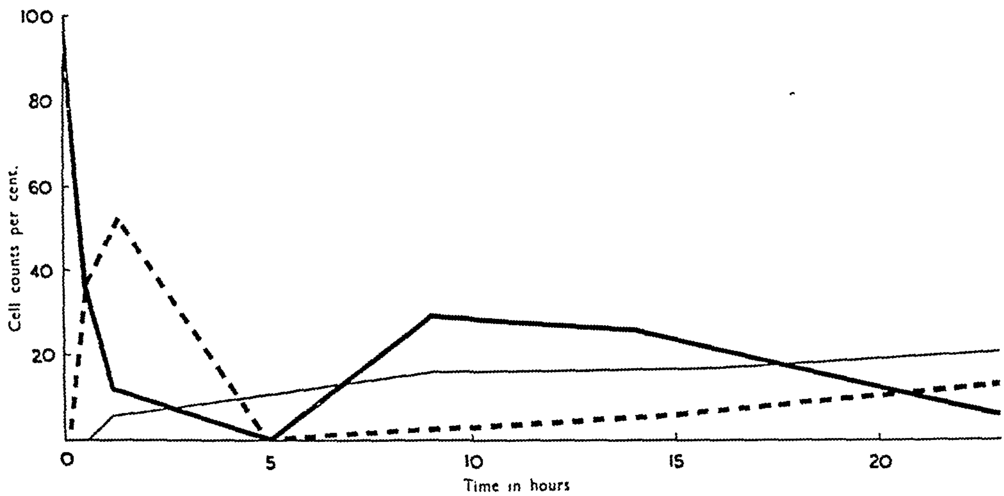

Fig. 3

Graph showing reduction in mitosis and occurrence of abnormal mitosis and cell degeneration in tissue cultures of avian fibroblasts exposed to 1000 r of X rays.
——— Mitosis. --- Abnormal mitosis. ——— Cell degeneration.

DISCUSSION

Although the dose-rate varies in the β-ray experiments as the three sources available were, unfortunately, not of equal strength, there is no apparent difference in effect. For instance, the results obtained at 30 minutes and 15 hours (dose-rate 74 r/min., Table III, col. H) agree with those seen at 80 minutes and 24 hours (dose-rate 200 r/min.). The radiation effects seem independent of dose-rate over this range of dose-rate. This result also suggests that any different response of the cells to X rays (dose-rate 100 r/min.) cannot be due to an intensity effect.

The comparison of the two results obtained after β and X irradiation show *qualitatively* similar findings. Both irradiations are followed by inhibition of mitosis and the production of abnormal mitotic and degenerate cells. The results of the area measurements suggest that the total damage produced is also of the same order in both cases.

The time, however, at which the main radiation effects appear differs markedly according to which type of radiation is used. β radiation produces the most marked effect shortly after exposure: this suggests that a large proportion of dividing cells are injured during irradiation. They are unable to complete cell division, become abnormal, and some of them break down. Thus the presence of degenerate cells so shortly after β irradiation is not related to a return of mitotic activity, but is due to the death of abnormal mitotic cells and probably of resting cells as well. On the other hand, mitotic recovery is fairly rapid.

After the same dose of X rays the damage is more delayed and the greatest effect is seen 5 and 24 hours following exposure. Results of earlier experiments have shown that degenerate cells observed after X-ray doses of 100 r–1000 r were always due to the breakdown of cells attempting division (Lasnitzki, 1943). An immediate effect on mitotic and resting cells similar to that seen after exposure to β rays was, however, observed after X-ray doses of 2500 r–10,000 r (Lasnitzki, 1943).

An early occurrence of degenerate cells unrelated to mitotic recovery was also found in the developing rat retina after exposure to neutrons (Spear and Tansley, 1944) and to an even greater extent in tadpoles exposed to α rays (Gray and Tansley, unpublished work).

ACKNOWLEDGMENTS

It is much to be regretted that Dr. D. E. Lea, who did all the physical work for this paper, did not live to see it published.

I should like to thank Dr. E. Brettscher for the loan of the β-ray sources and Dr. F. G. Spear for his active participation in the experiments, and his advice and criticism in the preparation of this manuscript.

SUMMARY

Tissue cultures of avian fibroblasts were exposed to a dose of 1000 r of pure β rays from uranium UX 1. Alteration in mitosis and the production of abnormal mitotic and degenerate cells were examined quantitatively for a period of 24 hours following irradiation.

A steep fall in mitosis, the appearance of abnormal mitotic figures and degenerate cells were observed shortly after exposure. This was followed by a return of mitotic activity accompanied by more abnormal mitosis and cell degeneration. Mitotic recovery was half the normal value at the end of the observation period.

A comparison with changes seen in tissue cultures treated with the same dose of X rays shows that the effect is qualitatively similar and the total damage produced of the same order in both cases, but that the time relation differs markedly in the two experiments. β irradiated cultures show the greatest effect shortly after exposure and an early recovery, while after X rays the radiation effect is delayed and recovery is slow.

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THE TREATMENT OF CANCER OF THE MAXILLARY ANTRUM BY RADIUM

By Margaret C. Tod, F.R.C.S.E., F.F.R.
Christie Hospital and Holt Radium Institute, Manchester 20

CANCER of the Maxillary Antrum is a form of malignant disease which presents special problems. Growth begins in a small cavity surrounded by bone and is often far advanced when first seen. The last stages are very distressing with severe pain, great deformity and repeated hæmorrhages sometimes continuing over months before local extension kills a victim seldom released by more merciful metastases. It is, therefore, of great importance to assess any simple method of treatment which may provide a fair chance of cure in early cases and good palliation in late cases.

This paper describes the method of treatment which has been used at the Holt Radium Institute during the last ten years and gives some of the results obtained. I believe that this method meets the requirements and is acceptable in a high proportion of cases even although success is often obtained at the cost of a minor operation to clear from the cavity the necrotic material produced by the irradiation.

It is not necessary in an English publication to give a clinical description of the disease and the many forms which it may take. In the Skinner lecture for 1943, Windeyer gave a classic description which cannot be bettered, and in an earlier paper from the Holt Radium Institute, Nuttall (1938) discussed some of the difficulties of diagnosis. I shall, therefore, begin with the material available for study and then describe the

Fig. 1.
Radiograph showing early carcinoma of the right antrum. There is early erosion of the lateral wall, adjacent floor and alveolus. Nose and orbital fossa intact.

Fig. 2.
Radiograph showing late carcinoma of right antrum. Roof and outer wall are destroyed and zygoma extensively involved.

evolution of radium treatment during the period under review. The material consists of 222 cases treated for tumours of the maxillary antrum at the Holt Radium Institute from 1932 to 1941. A five year follow-up is available for every case except one which was diseased when last seen and has been counted as dead from cancer. No standard clinical staging has been devised for cancer of the antrum, so the following division into early and late cases is suggested to facilitate assessment of results. "Early" cases are in general those in which, although there may already be destruction of bone, it is limited to one, or at most two, adjacent walls of the cavity and it is estimated that the whole tumour would be included in a sphere of 4 cm. in diameter (Fig. 1). "Late" cases are those which show by external swelling, or by widespread destruction of bone, that the tumour has spread beyond the antrum into the mouth, cheek, orbit or pterygoid region. Such a tumour would not be contained within a sphere 4 cm. in diameter. All cases with involvement of lymph nodes are classed as "late" (Fig. 2).

TABLE I
RESULTS OF TREATMENT AT FIVE YEARS. ALL CASES

Stage	*Number Treated*	*Well*	*Diseased*	*Dead of Disease*	*Dead Inter-current*	*5 Year Survival*
Early ..	95	29	5	54	7	36%
Late ..	127	17	3	107	0	17%
Total ..	222	46	8	161	7	25%

The first table shows the results for all cases treated, but having placed the total figures on record I shall discuss only those cases for which the special method of radium treatment was used and two small groups in which it is contra-indicated. Of the 222 cases 100 were treated by the method to be described; the two further groups consist of 19 cancers of mixed salivary type and 18 lymphosarcomas. This leaves 85 cases treated by other methods, some by a combination of surgery and radium, the rest, mainly advanced lesions, by X ray alone.

The five year survival figure of 25 per cent. is reasonably satisfactory and is similar to that of Windeyer for his group of cases treated at the Middlesex Hospital in the years 1925 to 1937—20·7 per cent. symptom free at five years.

The method of treatment to which attention is drawn is the application of radium in its simplest form, a tube placed in the centre of the tumour. This technique evolved slowly through the combination of surgery with radium. Surgical excision alone often fails completely to remove all malignant tissue so that radium began to be inserted in an attempt to extend the scope of the operation. A combined method was used for the majority of the cases in this series treated in the years 1932 to 1937. The usual procedure was lateral rhinotomy with excision of the main mass of tumour. A large ball or cylinder of sponge rubber cut to shape was inserted into the resulting cavity to carry a central tube of radium. The dose was calculated on the surface of the rubber container and was usually about 8000 r in ten days. Sometimes very large or irregular cavities called for the insertion of two or even three radium sources. Unfortunately, although this method was moderately successful even in advanced cases, the operative mortality was high; twelve out of forty-eight cases treated died in the immediate post-operative period of hæmorrhage or sepsis. It was clearly too radical for old patients or those whose general condition was unsatisfactory and it was suggested that a tube of radium inserted into the tumour with no attempt at excision was worth a trial. A comparatively small sample showed that it was possible to get satisfactory results in the same type of case which responded to the combined treatment with practically no risk of immediate complications. The tumour now remains in position and takes the place of the sponge rubber as a radium container at the surface of which the dose of irradiation is calculated. The intention is to raise a zone of tissue which encloses the tumour to radiotherapeutic tumour lethal dosage. To do this a tissue necrosis dose must be accepted within the tumour itself with a deliberate decision to take the high dose within a sphere 1½-2 cm. in radius. This procedure

leads to no severe symptoms provided there is satisfactory drainage through the hole by which the radium was inserted. Intra-tracheal anæsthesia should be used with the pharynx packed. The Caldwell Luc approach may be convenient or it may be possible to push the tube through a hole in the palate where erosion of bone has allowed the downward growth to reach the mouth. The exact position of the tumour should be carefully studied on radiographs which should be compared with a skull to determine the exact limits of extension into bone so that the tube may be placed as near the centre as possible. Sometimes it should appear almost vertical on the films taken to show its position, but with those tumours which appear in the sulcus between gum and cheek it may lie diagonally across the antrum. A tube containing 25 mgm. of radium element in an actual length of about 3 cm. is convenient and it should be covered with thin rubber projecting beyond the tube at one end. The tube is inserted into the antrum with the projecting rubber at the lower end, as shown in Fig. 3. It is now necessary to anchor the tube in position by a strong thread which passes through the rubber and is taken out through the whole thickness of the cheek where it is tied as a stay suture protected by rubber tubing, as shown in Fig. 4. It was found that if the needle was passed from below, upwards through the tumour, malignant cells might be implanted in the track so two needles must be used passing the two lengths of stay suture from above downward to catch and anchor the projecting rubber maintaining a steady pull upward. A thread is also taken out through the mouth and fixed to the cheek so that the radium may be removed simply by cutting the stitch on the cheek. A dose of 8000 r to 10,000 r in seven to ten days is taken at a point 2 cm. from the central radium source (Figs. 5 and 6). Occasionally with a very large tumour two tubes are used, either as a line source or as two separate foci. When two separate sources are used a careful physical check is needed as the shape of the isodoses round two tubes which are not parallel and whose distance apart it is not easy to control may give a surprising

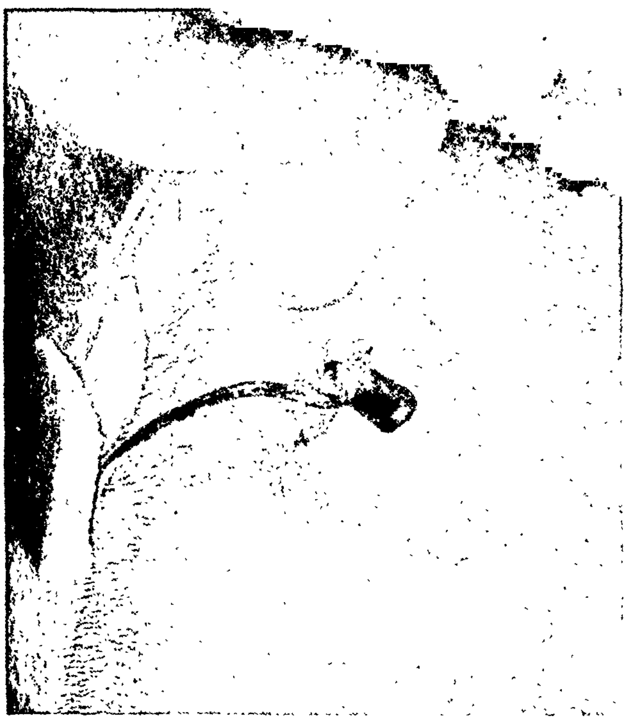

Fig. 3.
Antrum tube inserted through the canine fossa with rubber tube projecting into mouth. The anchoring stitch passes through the rubber at the level of the opening in the bone.

Fig. 4.
The anchoring stitch protected by rubber tubing at the outside of the cheek with the silk from the radium tube coming out of the mouth and fixed with elastoplast.

result when accurate measurement on films is obtained.

It is clear that the dose delivered must destroy the tumour and normal tissue within the 2 cm. radius. In the ideal case the amount destroyed is small and the debris drains into the mouth through the hole made for the insertion of radium with a final result almost exactly the same as that of combined treatment by surgery and radium but obtained with less risk. If on the other hand the tumour is a large one with considerable destruction of bone, sequestration is slow, and dying bone may interfere with drainage, resulting in sepsis and severe pain. It is then necessary to operate to enlarge the opening and clear out the retained slough and dead bone. As a rule the operation is easy and gives immediate relief. Nor is such secondary treatment needed only after the use of a central tube; it is also needed in a considerable proportion of the cases treated by the combined method.

Penicillin has proved most useful in reducing the incidence of pain due to sepsis and has made it easier to advise this method without fear that it will produce a distressing reaction. Another advantage which facilitates the choice of this treatment is that even for the cases in which it fails it has high value for palliation. Recurrence from an outgrowth of the tumour which lay beyond the zone of full irradiation must often occur, but there may be a long latent period, and the tumour may grow back into the cavity and kill by hæmorrhage without causing much pain.

The results of treatment by antrum tube are shown in Table II.

This table shows the result of treatment for all cases, but the main use of the method is in the treatment of squamous carcinoma—the common tumour of the maxillary antrum. Only sixty-eight of the cases treated had a pathological report of squamous carcinoma, of the others three were mixed salivary tumours, two sarcomas, two transitional cell carcinomas and one an adamantinoma. The remainder of the cases had no pathological report but only two of them survived five years. The results for the treatment of squamous carcinoma which follow are still far from satisfactory but they show that this

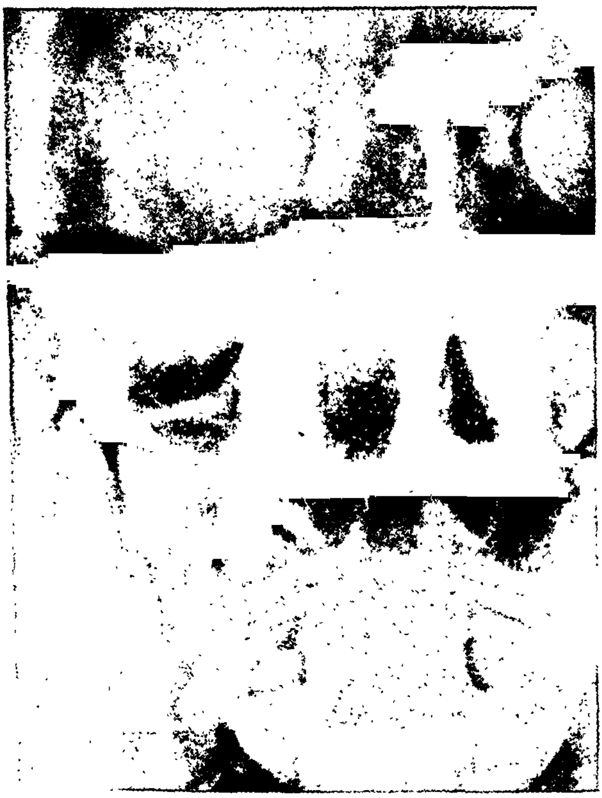

FIG. 5.
Antrum tube in position.

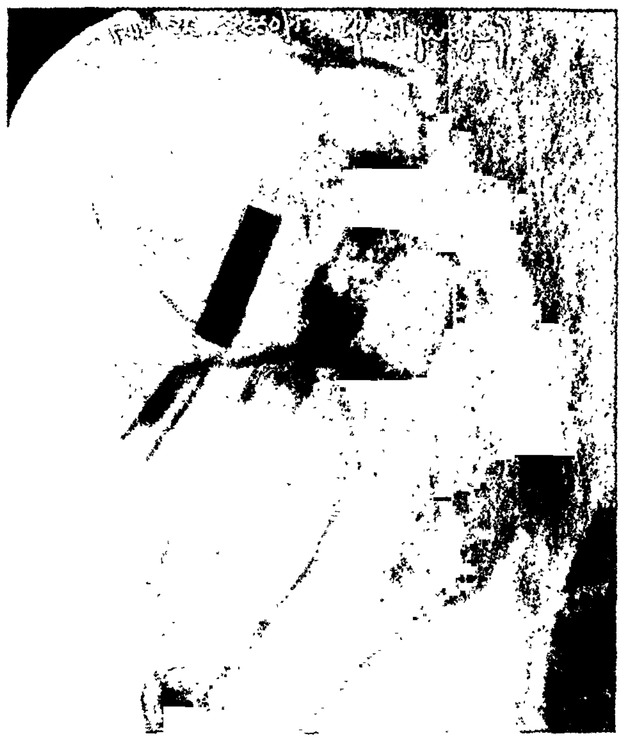

FIG. 6.
Lateral view of same case.

condition, the much feared "cancer of the face", can be controlled and that early diagnosis is the key to success.

Although squamous carcinoma is the common tumour of the antrum it is only one of many. The different forms of cancer, sarcoma and dental tumours found in the maxilla are of great interest to the pathologist but I only propose to mention two, the slow growing carcinoma usually described as "of mixed salivary type"—nineteen cases—and the reticulo-endothelial neoplasm probably most correctly described as "lymphosarcoma"—eighteen cases. These tumours differ so much from squamous carcinoma in their response to radiation that it is very important that they be distinguished and appropriately treated. For this reason it is always important to obtain a biopsy before beginning the treatment of a tumour of the maxilla.

TABLE II

Results of Treatment by Antrum Tube at Five Years

Stage	*Number Treated*	*Well*	*Diseased*	*Dead of Cancer*	*5 Year Survival*
Early ..	48	16	3	29	38%
Late ..	52	6	1	45	13%
Total ..	100	22	4	74	26%

TABLE III

Results of Treatment of Proved Squamous Carcinoma by Antrum Tube at Five Years

Stage	*Number Treated*	*Well*	*Diseased*	*Dead of Cancer*	*5 Year Survival*
Early ..	35	12	0	23	34%
Late ..	33	4	1	28	15%
Total ..	68	16	1	51	24%

TABLE IV

Results of Treatment by Combined Surgery and Irradiation of Tumours of Mixed Salivary Type at Five Years

Stage	*Number Treated*	*Well*	*Diseased*	*Dead of Cancer*	*5 Year Survival*
Early ..	11	2	4	5	—
Late ..	8	0	2	6	—
Total .	19	2	6	11	42%

TABLE V

Results of Treatment of Lymphosarcoma of the Antrum at Five Years

Stage	*Number Treated*	*Well*	*Diseased*	*Dead of Cancer*	*5 Year Survival*
Early ..	11	6	0	5	—
Late ..	7	3	0	4	—
Total ..	18	9	0	9	50%

The tumours of mixed salivary type are more malignant than the usual "mixed parotid tumour" and are in our experience very radio-resistant so that surgical excision is the main line of treatment. Some such cases in this series were treated by excision together with radium but there is little evidence that radiation prevents local recurrence which is distressingly frequent. A patient may live for many years undergoing one operation after another and finally die in misery in spite of all efforts. Even if some form of irradiation is projected, surgery must be fully radical, attempting a complete removal and remembering that this is probably the only chance of cure. Five year figures are of little value because of the slow growth of this tumour and the small number of cases, but the proportion diseased shows the inadequacy of treatment.

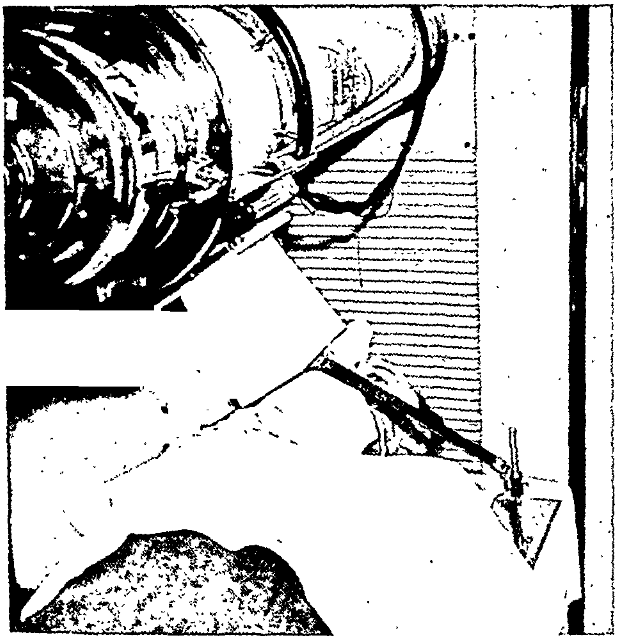

Fig. 7.
Trunk Bridge used for Beam Direction of 4 field set-up using fields 20 × 10 cm. for the treatment of lympho-sarcoma of the antrum with involvement of cervical lymph nodes.

The reticulo-endothelial tumours are, on the other hand, sensitive to radiation and when biopsy shows that one of these sensitive sarcomas is present, radium therapy is contra-indicated and X-ray therapy of the whole region is the best method of treatment. In general these sarcomas should be treated with fields which include the tumour with a surrounding zone much larger than that required for carcinoma together with the groups of nodes in the lymphatic drainage area. In practice this means that the whole head and neck from the orbital ridge above to the clavicle below must be irradiated. For this purpose four fields are used, the Trunk Bridge offering the most convenient way of ensuring homogeneity (Fig. 7). The eyes must be included because of the position of the ethmoids. A dose of 3000 r in three weeks is well tolerated. Once the disease has spread to other regions the prognosis, like that of a generalised reticulosis, is poor although local resolution of the tumour will probably be obtained.

Finally, Table V shows results for lymphosarcoma mainly treated by X-ray therapy although some failures are included which were due to proceeding to surgical excision without first taking a biopsy.

Summary

The results of treatment by radiation of carcinoma of the maxillary antrum are given for the years 1932-1941, with particular reference to a simplified method of radium treatment used in the latter half of that period. This consists simply of the insertion of a single tube of radium into the tumour—an operation practically free from immediate risk. The types of tumour for which this method is contra-indicated are mentioned.

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A THEORETICAL STUDY OF THE RESULTS OF IONIZATION MEASUREMENTS IN WATER WITH X-RAY AND GAMMA-RAY BEAMS

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PART I—METHODS OF CALCULATION

Introduction

The aim of this investigation is to determine how far the results of depth dose measurements in water with X rays and γ rays can be derived from theoretical considerations. If satisfactory theoretical methods could be found capable of yielding results in good agreement with experiment, they might be applied with advantage to the study of effects where the experimental evidence is conflicting or to those radiation conditions where little or no experimental work has yet been done.

Much experimental work on depth dose has been reported in recent years, but there has been considerable lack of agreement between results of different workers. However, the Depth Dose Survey of Mayneord and Lamerton (1941) gives mean values for depth dose and backscatter over a wide range of radiation conditions which can be used as a check on the theoretical work.

Interaction Between X Radiation and Matter

Scattering and absorption processes

For the qualities of radiation dealt with in this investigation the main scattering process will be the Compton Effect, and the electronic scattering and absorption constants taken will be those derived from the Klein-Nishina formulæ. The extent to which unmodified scatter will play a part can be determined from the formula given by Sommerfeld (1930). Applying this formula to the case of oxygen (atomic number 8) the following values are obtained for the angle θ at which the ratio of intensities of modified to unmodified scatter is 1, 10, and 100, for wavelengths 0·3, 0·2, 0·1, and 0·01 Å.

TABLE I

Wavelength Å	*Ratio* = 1 θ	*Ratio* = 10 θ	*Ratio* = 100 θ
0·3	43°	71°	121°
0·2	29°	45°	71°
0·1	14°	22°	34°
0·01	1·4°	2·2°	3·4°

Since this study is concerned chiefly with wavelengths shorter than 0·2 Å and with water and air, materials of low atomic number, the unmodified scatter will not be appreciable except for the smaller angles of scattering where the difference between the Klein-Nishina and the classical $1 + \cos^2\theta$ formula is small enough to be neglected. Therefore it will be assumed that all electrons scatter according to the Klein-Nishina rule.

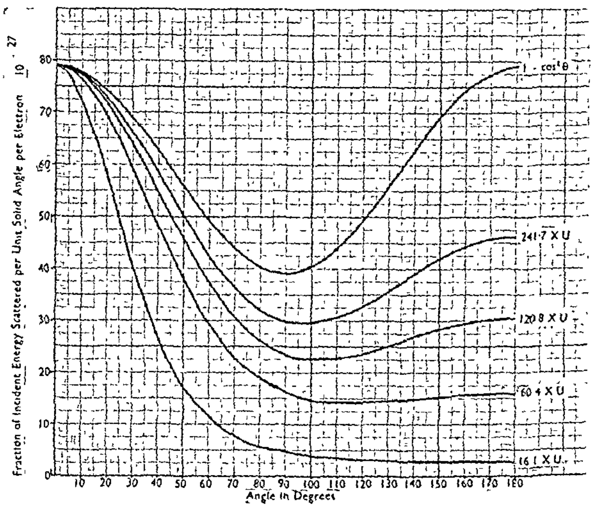

Fig. 1.

Fraction of incident energy scattered per unit solid angle per electron.

Klein-Nishina formula figures given by Tarrant (1932).

The values of the electronic scattering and absorption coefficients ${}_e\sigma_s$ and ${}_e\sigma_a$ used will be those calculated from the Klein-Nishina formulæ by Read (1944). The Klein-Nishina values for the fraction of incident energy scattered per unit solid angle per electron have been taken from a paper by Tarrant (1932) and these values, for certain wavelengths, are shown plotted in Fig. 1.

The photoelectric absorption coefficients used will be those determined from the formula given by

Walter (1927): ${}_e\tau = 2{\cdot}64 \times 10^{-26} \times Z^{2\cdot94} \times \lambda^3$, for values of λ shorter than the wavelength of the characteristic K radiation of the material.

The total real absorption coefficient for the electron is given by $({}_e\sigma_a + {}_e\tau)$ and the way in which this varies with wavelength for air is shown in Fig. 2.

Nuclear interaction can be neglected over the range of wavelengths dealt with in this investigation since only elements of low atomic number will be considered.

WORK OF OTHER INVESTIGATORS

Attempts to calculate the variation of intensity along the central axis of a beam of X radiation in a scattering medium have been made by Ruby Payne-Scott (1937) and R. H. de Waard (1946). Calculations of less general application are reported by Cassen, Corrigan, and Hayden (1938), and by Lauritsen (1938). Payne-Scott calculated the intensity along the central axis of a circular parallel beam in water, considering only single-scattering. Her method depends on a numerical integration of the Klein-Nishina scattering function and can be applied to any wavelength. Since no account was taken of multiple scattering the values obtained for the scattered intensity at a depth in water and for the backscatter from the surface were on the whole considerably less than those derived from the experimental values. Nevertheless, her contribution is of considerable value in showing a method of approach to the problem.

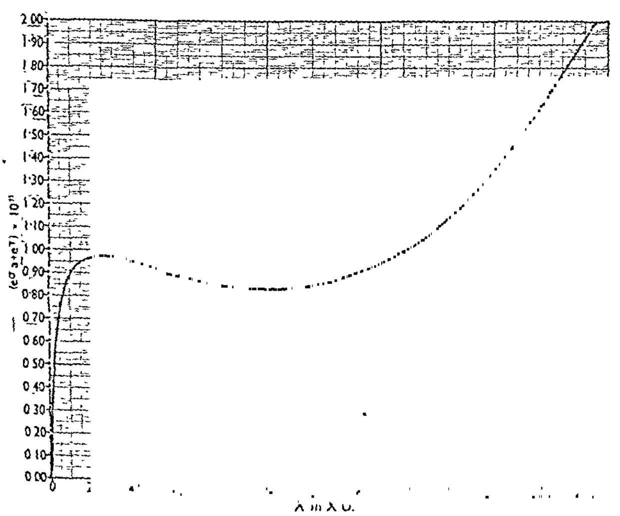

FIG. 2.

Variation with wavelength of $({}_e\sigma_a + {}_e\tau)$ for air.
${}_e\sigma_a$ calculated from Klein-Nishina formula.
${}_e\tau$ calculated from Walter's formula.

De Waard approached the problem from the point of view of the intensity of scattered radiation reaching the film in radiography. Starting from the assumption that the radiation was scattered according to the classical $1 + \cos^2\theta$ formula, an expression was obtained for the intensity of once-scattered radiation at any depth in the medium. The variation of intensity of once-scattered radiation with depth was then expressed as the sum of exponential terms and an integral equation obtained, after further simplifying assumptions, from which the intensity of multiple scatter at any depth could be derived.

De Waard compared his theoretical values of the ratio of scattered to primary radiation at different depths with some early experimental data obtained by Wilsey (1921), and the agreement is surprisingly good in view of the assumptions made by de Waard and the fact that Wilsey used photographic methods for measurement of intensity.

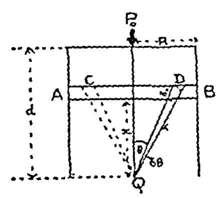

FIG. 3.

Since de Waard assumes the classical theory of scattering, his methods cannot be applied directly to the present investigation, although, as will be seen, they can be adapted to be of more general use.

The method of calculation employed by Payne-Scott is essentially as follows:

Consider a parallel beam of monochromatic radiation, having circular cross-section of diameter $2R$, incident normally on the surface of the water.

The intensity of radiation at a point Q on the central axis of the beam will be the sum of (*a*) the intensity of the primary radiation at Q, (*b*) the sum of the intensities of the scattered radiation reaching Q from all points within the irradiated volume.

Let the point Q (Fig. 3) be at a depth d below the surface of the water.

Consider the element of volume AB, in the form of a thin disc at a distance x above Q.

If the intensity of the incident radiation at the surface of the water is P_o, then the intensity of the

primary radiation at the disc AB is $P_{(d-x)} = P_o e^{-\mu_o(d-x)}$ where μ_o is the total linear absorption coefficient of the primary radiation, that is, the linear coefficient corresponding to the total electronic absorption coefficient $({}_e\sigma_a + {}_e\sigma_s + {}_e\tau)$.

For convenience the linear absorption coefficient corresponding to the electronic absorption coefficient σ will be represented by ${}_m\sigma$, so that $\mu_o = {}_m({}_e\sigma_a + {}_e\sigma_s + {}_e\tau)$.

Now consider the scattered radiation reaching the point Q from a small annular element CD in the disc AB (Fig. 3).

The radiation scattered from each electron in the annulus would produce at Q (in the absence of further absorption) an intensity $\frac{P.f(\theta)}{r^2}$ where P is the intensity of the radiation incident on the annulus and $f(\theta)$ is the fraction of the incident intensity scattered per unit solid angle per electron in the direction θ, given by the Klein-Nishina formula.

Then the intensity of the radiation at Q scattered from the annular element CD is

$\delta I = \frac{N_1 P}{r^2} f(\theta).2\pi r^2 \sin\theta\delta\theta\delta r$ where N_1 is the number of electrons per c.c. of water.

$= KP_o e^{-\mu_o(d-x)} f(\theta) \sin\theta\delta\theta\delta r$ where $K = 2\pi N_1$.

If the effect of unmodified scattering is small enough to be neglected, the wavelength of the radiation scattered at an angle θ can be determined from Compton's theory. Its total linear absorption coefficient, to be denoted by μ_θ, will be different from that of the primary radiation.

Then taking absorption into account,

$$\delta I = KP_o e^{-\mu_o(d-x)} \times e^{-\mu_\theta r} f(\theta) \sin\theta\ \delta\theta\ \delta r.$$

But $r = x/_{\cos\theta}$

Whence $$\delta I = KP_o e^{-\mu_o d} e^{x\left(\mu_o - \frac{\mu_\theta}{\cos\theta}\right)} \times f(\theta) \tan\theta\ \delta\theta\ \delta x \quad \ldots\ldots\ldots\ldots (1)$$

and the total intensity of the scattered radiation at Q is given by

$$I_d = KP_o e^{-\mu_o d} \int\int e^{x\left(\mu_o - \frac{\mu_\theta}{\cos\theta}\right)} \times f(\theta) \tan\theta\ d\theta\ dx \quad \ldots\ldots\ldots\ldots (2)$$

$$= KP_o e^{-\mu_o d} \int \gamma dx, \text{ where } \gamma = \int e^{x\left(\mu_o - \frac{\mu_\theta}{\cos\theta}\right)} \times f(\theta) \tan\theta\ d\theta$$

The limits of integration for θ depend on the size of the field. The upper limit for x is the depth below the surface at which the intensity of scattered radiation is to be calculated, and the integration for negative values of x must be carried out until the contribution to the intensity from backscatter becomes negligible.

The above formula for I_d cannot, in general, be expressed in terms of simple algebraic functions, and graphical methods have to be employed for the integration.

In de Waard's treatment $f(\theta)$ is taken as $(1+\cos^2\theta)$ and μ_θ is taken equal to μ_o so that equation (1) has the form

$$\delta I = KP_o e^{-\mu_o(d-x)} \times e^{-\frac{\mu_o x}{\cos\theta}} \times (1 + \cos^2\theta) \tan\theta\ \delta\theta\ \delta x$$

Putting $z = \mu_o r = \mu_o x \sec\theta$

$$\delta I = KP_o e^{-\mu_o(d-x)} \left\{ \frac{e^{-z}}{z} + \frac{(\mu_o x)^2\ e^{-z}}{z^3} \right\} \delta z \delta x$$

This expression can be integrated with respect to z using tables of the exponential integral $\left(\int_1^\infty \frac{e^{-u}}{u} du\right)$, so that the contribution of once-scattered radiation at Q from a disc AB can be determined directly. De Waard found that the values obtained for this integral in the cases investigated could then be expressed as the sum of exponential terms $k_1 e^{-\gamma_1 x} + k_2 e^{-\gamma_2 x}$, where k_1, k_2, γ_1, and γ_2 are constants. This empirical expression could then be integrated with respect to x to give the total intensity of once-scattered radiation at a depth.

The variation of intensity of once-scattered radiation with depth was now itself expressed as the sum of exponential terms. An integral equation from which the intensity of multiple scattered radiation could be obtained was then derived on the assumptions that the intensity of scattered radiation was constant over any horizontal plane and that the angular distribution of scattered radiation originating in any small volume of the medium followed the $1 + \cos^2\theta$ rule.

FACTORS INVOLVED IN CALCULATIONS OF DEPTH DOSE

Payne-Scott's method of calculation gives the intensity of once-scattered radiation at any depth when the medium is irradiated by a parallel beam of monochromatic radiation. In practice, however, multiple scattering plays a large part in determining the intensity at a depth except for very short wavelengths. Also the incident beam of radiation is

heterogeneous and divergent, and dose is measured, not intensity. A satisfactory theoretical treatment of the problem must therefore take account of the factors: (*a*) multiple scattering, (*b*) divergence of beam, (*c*) relation between dose and intensity, (*d*) heterogeneity of incident radiation.

Multiple scattering

A strict calculation of the effect of multiple scattering presents very great difficulties in view of the nature of the Klein-Nishina function and the fact that the wavelength change at each scattering involves a change in absorption coefficient and angular distribution of scatter. The most hopeful line of attack is to seek an approximate method which can give reasonably satisfactory results along the central axis of the beam.

One approach lies in the consideration of possible equilibrium conditions with regard to the scattering process. Assume first that a small element of volume δv in the medium and on the central axis of the beam receives as much scattered radiation as it gives out. The intensity along the central axis of the beam will then be determined by the factor $e^{-}{}_m(\sigma_a + \tau)d$ where ${}_m(\sigma_a + \tau)$ is the linear absorption coefficient of the primary radiation corresponding only to real absorption. Now the energy of scattered radiation given out per second by a small volume δv is proportional to $\Sigma I_\lambda \sigma_{s,\lambda} \delta v$ where I_λ is the intensity of radiation of wavelength λ reaching σ_v, and $\sigma_{s,\lambda}$ is the scattering absorption coefficient for that wavelength. Therefore, assuming that σ_s does not change rapidly with wavelength, the scattered radiation from δv will be approximately proportional to the total intensity of the radiation (primary + scattered) incident on it. The amount of scattered radiation received by δv will depend on the extent of the scattering medium and the variation of the total intensity of radiation over the medium, particularly in the regions from which δv receives the greatest amount of scatter.

This method of approximation takes no account of size of field. In general, it will give too high values for the intensity near the surface. At points at a depth it will give too high or too low a value, depending on the depth, the size of the field, the F.S.D. (since this will affect the variation in intensity of the primary radiation), as well as on the wavelength of the primary radiation. The initial assumption, that δv receives as much scattered radiation as it gives out, will, in fact, hold only when the variation of the intensity of the primary radiation is small over a distance comparable with the mean range of the quanta.

In practice, where this condition is not obeyed, an additional complication is introduced by the scattering not being spherically symmetrical and varying with the wavelength of the incident radiation.

An assumption that might be of more practical value than the previous one is that an equilibrium is set up with respect to the scattered radiation of orders higher than the first. Assume that the total energy of scattered radiation, of higher orders than the first, received by δv is equal to the energy lost by the scattering process in the passage of the once-scattered radiation to δv from its point of origin. The total amount of scattered radiation reaching δv would then be given by calculating for single-scattered radiation, as done by Payne-Scott, except that the real absorption coefficient ${}_m(\sigma_a + \tau)_\theta$ would be used in determining the attenuation of the once-scattered radiation reaching the given point instead of the total absorption coefficient ${}_m(\sigma_a + \sigma_s + \tau)_\theta$.

The formula for I_d (equation 2) would then become

$$I_d = KP_o e^{-\mu_o d} \int\int e^{x\left(\mu_o - {}_m\frac{(\sigma_a + \tau)_\theta}{\cos\theta}\right)} \times f(\theta) \tan\theta \, d\theta \, dx \qquad (3)$$

At first sight it would appear that this method of approximation should in general give too high values for the scatter at a depth since not all the energy lost by the scattering process in the passage of once-scattered radiation reaches the given point; some will be lost by passing out of the medium. This, however, is not the case and the method will be discussed further when the results of the calculations are given.

Correction for divergence of beam

With a divergent beam, correction must be made for (i) the decrease in intensity due to the inverse square law, and (ii) the increase in cross-section of the beam with depth.

A correction for (i) can be made when the diameter of the field is small compared with F, the distance from the source of radiation to the surface of the medium, in which case the intensity of the primary radiation over any plane parallel to the surface of the medium may be considered constant.

If P_o is the intensity of the primary radiation at the surface and P_h that over a plane at a depth h below the surface, then

$$P_h = P_o \times \frac{F^2}{(F+h)^2} \times e^{-\mu_o h}$$

With the nomenclature previously used $h = d - x$ and

$$I_d = KP_o \times \frac{F^2}{(F+d-x)^2} \; e^{-\mu_o d} \int \gamma dx \; \ldots\ldots \ldots\ldots\ldots\ldots \text{(see equation 2)}$$

If x is small compared with $F + d$, I_d can easily be shown equal to

$$KP_o \times \frac{F^2}{(F+d)^2} \; e^{-\mu_o d} \left\{ \int \gamma dx + \frac{2}{F+d} \int \gamma x \, dx \right\}$$

and this is quite a manageable form for the expression.

Another form for the correction follows from

$$\frac{F^2}{(F+h)^2} = e^{\frac{-2h}{F}} \text{ if } h/F \text{ is small}$$

$$\text{so that } P_h = P_o \times e^{-2h/F} \times e^{-\mu_o h} = P_o e^{-(\mu_o + 2/F)h}$$

Thus the effect of focal distance can be corrected for by adding to the absorption coefficient of the primary radiation the quantity $2/F$.

The correction for factor (ii) lends itself to no such simple approximation and the method used has been to estimate it from the variation of depth dose with field diameter obtained by calculation for parallel beams.

Relation between dose and intensity

The relation between the intensity I of a monochromatic radiation of wavelength λ and the dose D in röntgens will be given by $D = kI\,(\sigma_a + \tau)^{air}_{\lambda}$ where k is a constant.

For a heterogeneous beam of radiation the relation will be $D = k\Sigma I_\lambda (\sigma_a + \tau)^{air}_{\lambda}$. The wavelength distribution of energy in the radiation present at a depth in the medium will in general be different from that of the primary radiation, and thus, in general, the percentage depth dose will be different from the percentage depth intensity.*

For a monochromatic radiation, and if only single scattering is considered, a strict calculation of the dose can be made by multiplying the intensity of the once-scattered radiation reaching the chosen point from each small element of the volume by the factor $\left(\frac{\sigma_a + \tau}{\sigma_a + \tau}\right)^{air}_{\theta}{}_{o}^{air}$, $(\sigma_a + \tau)^{air}_{\theta}$ being the real absorption coefficient in air for radiation scattered at an angle θ, and $(\sigma_a + \tau)^{air}_{o}$ that for the primary radiation.

The formula for the dose at a depth d is then (see equation 2)

$$D_d = KP_o e^{-\mu_o d} \iint e^{x(\mu_o - \mu_0/\cos\theta)} \times \frac{(\sigma_a + \tau)^{air}_{\theta}}{(\sigma_a + \tau)^{air}_{o}} f(\theta) \tan\theta \, d\theta \, dx$$

In practice, however, the calculation of the dose cannot be made as simply as this, since in the first place the X-ray beams used will not be monochromatic, and secondly, multiple scattering will take place in the medium. The non-homogeneity of the radiation presents no bar to the theoretical treatment if the energy distribution of the spectrum be known, and a method of determining this is discussed later. However, the difficulties in the way of a direct theoretical treatment of the effect on dose of multiple scatter have already been discussed and the problem must be approached from other angles.

An indication of the relation between dose and intensity can be derived from a consideration of the variation of $(\sigma_a + \tau)^{air}$ with wavelength (Fig. 2), remembering that the change of wavelength occurring in a forward direction from a single scattering varies between 0 and 24·2 X.U., and the change in a backward direction between 24·2 and 48·4 X.U.

With primary radiations of short wavelength, up to about 10 X.U., the effect of scatterings of any order will be to increase the value of $(\sigma_a + \tau)^{air}$ for the scattered radiation. The value of the ratio

$$(\sigma_a + \tau)^{air}_{\theta} \Big/ (\sigma_a + \tau)^{air}_{o}$$

will then be greater than unity, and for these short wavelengths the ratio of the dose of secondary

* The dose or intensity at a depth is sometimes measured as a percentage of the dose or intensity of the *total* radiation at the surface, and sometimes as a percentage of the dose or intensity of the *primary* radiation at the surface. To avoid confusion the following nomenclature has been adopted:

"Percentage *depth* dose": the dose at a depth measured as a percentage of the total dose at the surface.

"Percentage dose": The dose at a depth measured as a percentage of the primary dose at the surface. The same distinction holds between "percentage depth intensity" and "percentage intensity". Following usual practice the value of the dose or intensity of the backscattered radiation at the surface is given as a percentage of the dose or intensity of the *primary* radiation. It is known as "percentage surface backscatter".

radiation to the dose of primary radiation at a given depth should be greater than the ratio of the intensities. The percentage depth dose obtained should therefore be greater than the percentage depth intensity, unless the effect were compensated by a sufficient difference between the values of percentage surface backscatter measured as dose and measured as intensity. Such compensation, however, is unlikely to occur, since the amount of surface backscatter for short wavelengths is known to be small.

The difference between the ratio of the doses and the ratio of the intensities of the secondary to the primary radiation will increase with decreasing wavelength, for the short wavelengths considered. However, the difference between percentage depth dose and percentage depth intensity will not increase to the same extent since the absolute amount of scatter decreases with wavelength.

For wavelengths in the region where the change of $(\sigma_a + \tau)^{air}$ is small there will be no great difference between the ratio of the doses and the ratio of the intensities of secondary to primary radiation at a depth. For wavelengths between 20 and about 80 X.U. the ratio of the doses at a given depth, considering scattered radiation of the first few orders, would be expected to be slightly less than the ratio of the intensities. For wavelengths longer than about 150 X.U. the ratio of the doses will be increasingly greater than the ratio of the intensities and this may mean that the percentage depth dose is considerably greater than the percentage depth intensity for these wavelengths.

A more quantitative approach is provided by the work of Clarkson and Mayneord (1939), who measured the depth dose for different field sizes and qualities of radiation, and at the same time made measurements on the change in quality of the radiation in its passage through the water, using their "double-chamber" method. In this way they obtained a value for the "equivalent wavelength" of the radiation at various depths under the different radiation conditions. Strictly, no one value of "equivalent wavelength" can be assigned to a heterogeneous beam of radiation since the value obtained will depend on the particular absorption or scattering process considered. This question will be discussed more fully later. However, it should be possible to use these values of "equivalent wavelength" to convert their experimentally determined values of depth dose approximately to values of depth intensity, which may then be compared with the theoretical determinations.

The effect of the heterogeneity of the beam

Let $I_\lambda d\lambda$ be the contribution to the total intensity of a heterogeneous beam from wavelengths between λ and $\lambda + d\lambda$. Let λ_e be the wavelength of the monochromatic radiation having the same absorption coefficient σ as the heterogeneous beam. Obviously the quality of the beam and thus the measured value of its absorption coefficient will

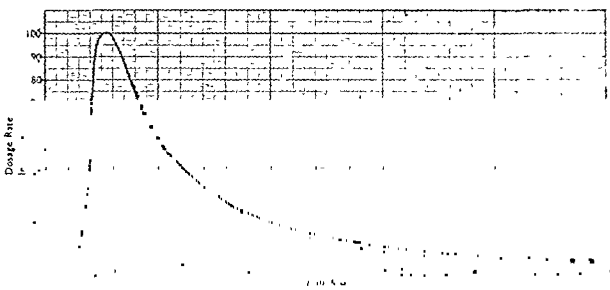

Fig. 4.
Wavelength distribution of dosage-rate and intensity. 200 kV radiation.
Filter 0·44 mm. Sn+0·25 mm. Cu+1 mm. Al.
H.V.L., 1·77 mm. Cu.
Full curve: Wavelength distribution of dosage-rate.
Broken curve: Wavelength distribution of intensity.

depend on the thickness of the absorber traversed, but considering only absorption through very thin layers of material $\sigma_{\lambda e} = \dfrac{\int \sigma_\lambda I_\lambda d\lambda}{\int I_\lambda d\lambda}$

Since the various absorption and scattering coefficients do not vary in the same way even for the same material, a different value of the "equivalent wavelength" λ_e will in general be obtained according to whether it is the total absorption, the real absorption, or the scattering effect that is being considered, and for the various absorption coefficients the value will also depend on the particular absorbing material chosen.

The extent of the difference can be determined only by considering actual examples of wavelength-energy distributions. Methods of determining the wavelength-energy distribution of a heterogeneous radiation from its absorption curve in a given material have been described by Silberstein (1933), and by Jones (1940). In his paper Jones gives as an example the determination of the wavelength distribution for a 200 kV radiation of half-value layer 1·77 mm. Cu, the result of which is shown in Fig. 4.

We have applied the same method to obtain the spectral distribution of a harder radiation, using the absorption data in copper given by Mayneord and Roberts (1935) for 380 kV radiation with a total filter of 3·5 mm. Cu, the half-value layer of this radiation being 4·25 mm. Cu. The wavelength distribution of dosage-rate and intensity calculated for this radiation are shown in Fig. 5.

Knowing the energy distribution in the spectrum

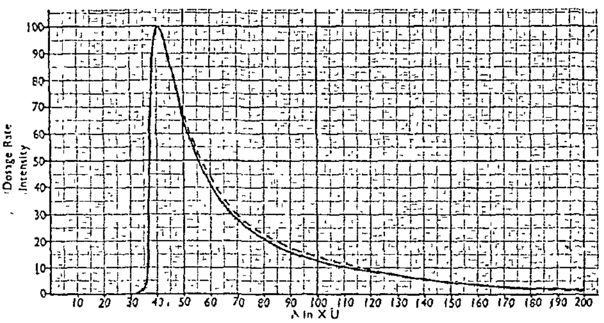

FIG. 5.

Wavelength distribution of dosage-rate and intensity.
380 kV radiation.
Filter 3·5 mm. Cu.
H.V.L., 4·25 mm. Cu.

Full curve: Wavelength distribution of dosage-rate.
Broken curve: Wavelength distribution of intensity.

and the variation with wavelength of the various scattering and absorption coefficients, the equivalent wavelength for any given scattering or absorption coefficient can be determined. The results are shown in Table II.

TABLE II

VALUES OF DIFFERENT "EQUIVALENT WAVELENGTHS"

200 kV constant potential radiation.
H.V.L. 1·77 mm. Cu.
Wavelength of monochromatic radiation having:

(a) Same H.V.L. in copper	120 X.U.
(b) Same total absorption coefficient (σ_s + σ_a + τ) in water	113 X.U.
(c) Same real absorption coefficient (σ_a + τ) in water	144 X.U.
(d) Same real absorption coefficient in air ..	141 X.U.
(e) Same scattering coefficient (σ_s) ..	104 X.U.

380 kV constant potential radiation.
H.V.L. 4·25 mm. Cu.
Wavelength of monochromatic radiation having:

(a) Same H.V.L. in copper	69 X.U.
(b) Same total absorption coefficient in water	64 X.U.
(c) Same real absorption coefficient in water	55 X.U.
(d) Same real absorption coefficient in air ..	55 X.U.
(e) Same scattering coefficient	63 X.U.

The extent of the hardening of the primary beam of the 380 kV radiation on its passage through water has been demonstrated by calculating the transmission through various depths of water, using the dosage-rate-wavelength distribution, and determining for each depth the wavelengths of the monochromatic radiation which would suffer the same absorption (Table III).

TABLE III

Depth	Value of transmission	Wavelength of monochromatic radiation having same value of transmission
5 c.m.	0·506	62 X.U.
10 cm.	0·259	60 X.U.
15 cm.	0·134	59 X.U.

METHODS OF CALCULATION

The methods of calculation employed are given in the Appendix which follows.

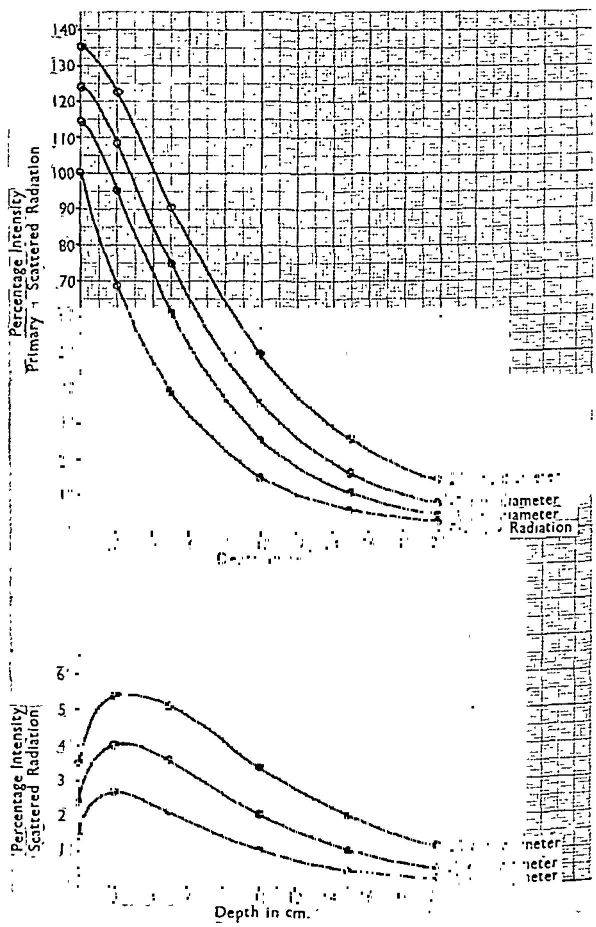

FIG. 6.

Calculations of depth intensity in water for $\lambda = 120{\cdot}8$ X.U.
F.S.D., 100 cm.

The significance of "equivalent wavelength" will be further discussed in Part II of this paper.

RESULTS OF CALCULATIONS

Calculations have been carried out for different field sizes for wavelengths of 120·8 X.U., 60·4 X.U., 16·1 X.U., 9·7 X.U., and 4·8 X.U., corresponding to half-value layers of 1·8 mm., 5·0 mm., 11·5 mm., 15·0 mm., and 20·0 mm. Cu, respectively. Certain calculations have also been done for wavelengths for the shorter wavelength radiations the dose values for the scattered radiation have been determined on the basis of wavelength change occurring in single scattering. Figs. 6–10 show results for the five different qualities of radiation. In these values no correction has been made for the increasing cross-section of the beam with distance.

It can be seen that for each quality of radiation and field size the scattered radiation reaches its maximum value at some distance below the surface, and that the depth at which this maximum occurs

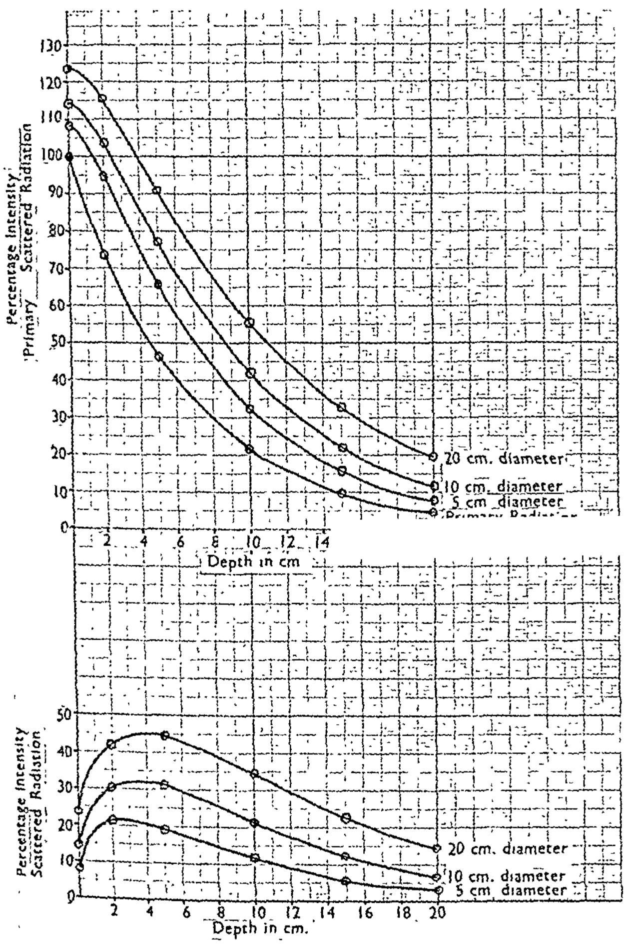

FIG. 7.
Calculations of depth intensity in water for $\lambda = 60{\cdot}4$ X.U. F.S.D., 100 cm.

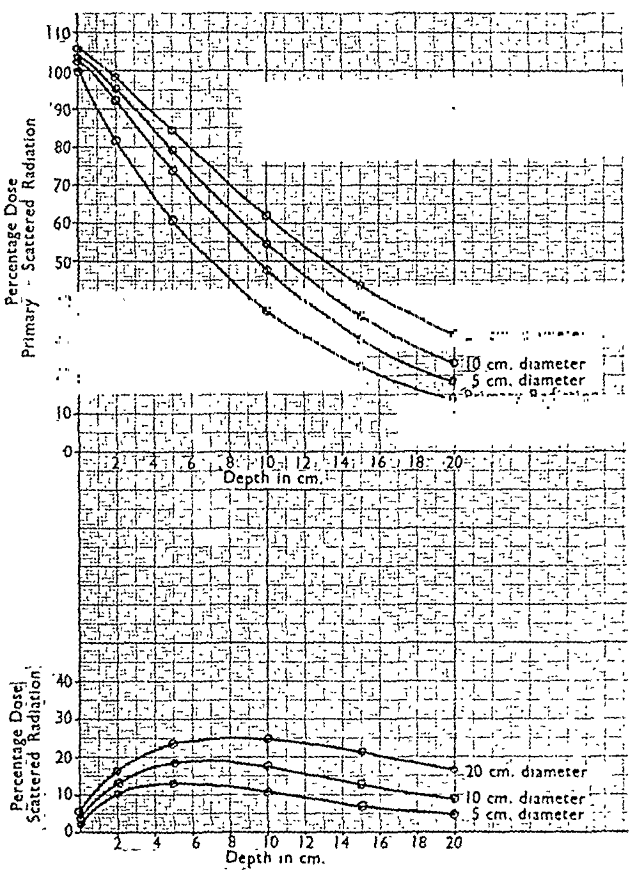

FIG. 8.
Calculations of depth dose in water for $\lambda = 16{\cdot}1$ X.U. F.S.D., 100 cm.

of 172 X.U. (H.V.L. 0·8 mm. Cu) and 242 X.U. (H.V.L. 0·33 mm. Cu).

The direct integration method has been used chiefly for the more detailed examination of 60·4 X.U. radiation. In most other cases graphical integration has been employed. For the radiation of wavelengths 120·8 X.U. and 60·4 X.U. the intensity of the scattered radiation has been calculated, while increases as the wavelength of the radiation decreases. The amount of scattered radiation at a given depth decreases for a given field size. Also the percentage surface backscatter for a given field size decreases with decreasing wavelength.

The comparison between these calculated values and experimental values will appear in Part II of this paper.

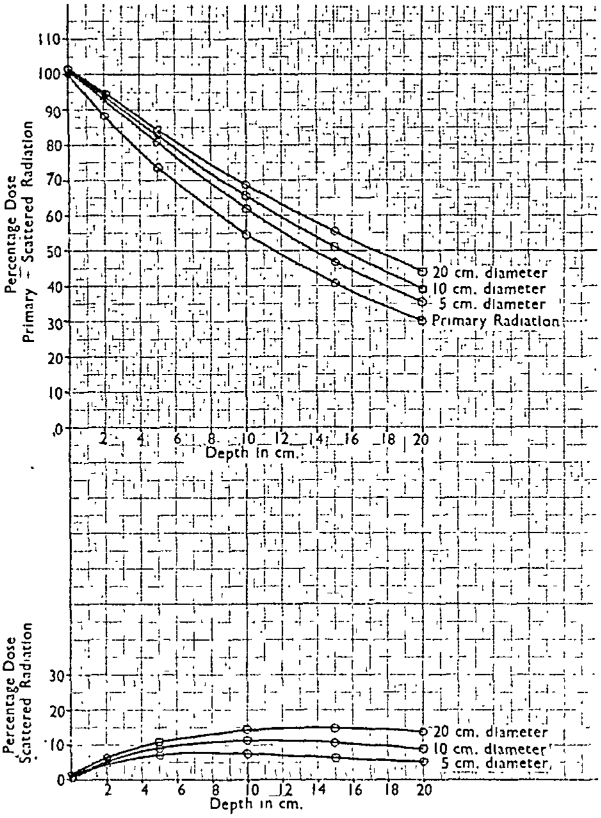

FIG. 9.
Calculations of depth dose in water for $\lambda = 9{\cdot}7$ X.U. F.S.D., 100 cm.

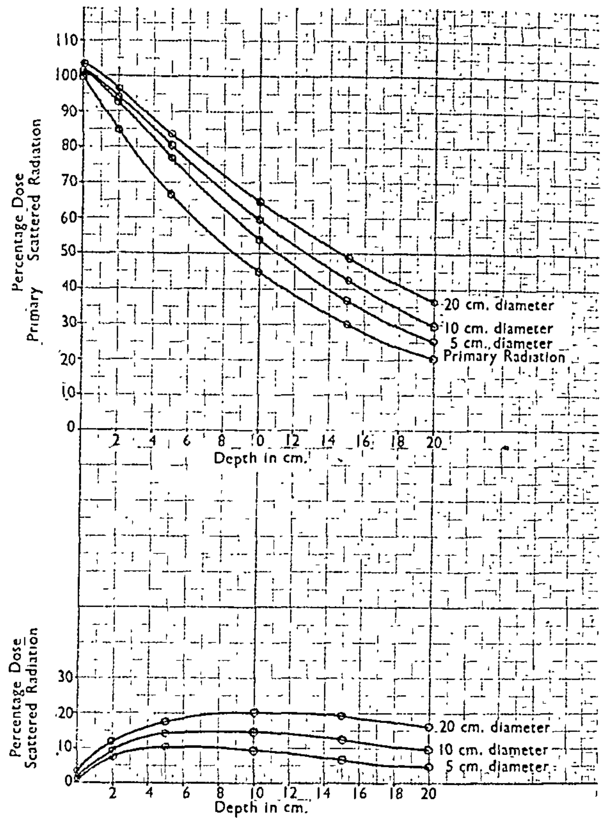

FIG. 10.
Calculations of depth dose in water for $\lambda = 4{\cdot}8$ X.U. F.S.D., 100 cm.

APPENDIX

METHODS OF CALCULATION

Numerical integrations

The formula for the intensity of scattered radiation at a depth d, using the approximation to multiple scattering described above is

$$I_d = KP_d \int\int \gamma dx$$

where $\gamma = \int e^{x\left(\mu_o - \frac{m(\sigma_a + \tau)_\theta}{\cos\theta}\right)} . f(\theta) \tan\theta \, d\theta$

the limits of integration being as given previously. This integration can be effected numerically in two parts, first with respect to θ. The value of γ is determined graphically for various positive values of x between 0·25 and 20 (this allows calculation of the intensity down to a depth of 20 cm.) and for negative values of x between $-0{\cdot}25$ and $-5{\cdot}0$. The backscatter from elements at a distance greater than 5·0 cm. is very small and can be estimated by extrapolation with sufficient accuracy. Now if the first method of correction for finite focal distance is to be applied

$$I_d = KP_d \int \left(1 + \frac{2x}{F + d}\right) \gamma dx$$
$$= KP_d \left\{ \int \gamma dx + \frac{2}{F + d} \int \gamma x dx \right\}$$

γ and γx are plotted against x, and $\int \gamma dx$ and $\int \gamma x dx$ determined from the area under the curve, the limits of integration being $x = d$ to $x = 0$ and $x = 0$ to $x = -\infty$

If dose is to be determined (on the basis of the wavelength change with single scattering) then the expression for γ must include the factor $\left(\frac{(\sigma_a + \tau)^{air}_{\theta}}{(\sigma_a + \tau)^{air}_{o}}\right)$

Approximate formula for $f(\theta)$

A more mathematical approach to the problem would be possible if the expression $f(\theta)$ of the Klein-Nishina formula could be simplified. Tests have shown that over a wide range of wavelengths the values of $f(\theta)$ for angles from 0 to 90° can be expressed in the form $f(\theta) = A + B\cos^2\theta$, where

A and B are constants for a particular wavelength. The approximate formulæ for three different wavelengths are given below:

$$241{\cdot}7 \text{ X.U. } (\alpha = 0{\cdot}1) \rightarrow 30{\cdot}6 + 48{\cdot}4 \cos^2\theta$$
$$120{\cdot}8 \text{ X.U. } (\alpha = 0{\cdot}2) \rightarrow 23{\cdot}4 + 55{\cdot}6 \cos^2\theta$$
$$60{\cdot}4 \text{ X.U. } (\alpha = 0{\cdot}4) \rightarrow 13{\cdot}0 + 66{\cdot}0 \cos^2\theta$$

For values of $f(\theta)$ from 90 to 180° an expression of similar form will hold, and in the case of wavelengths of 60 X.U. and less, $f(\theta)$ can be considered constant for $\theta = 90°$ to $\theta = 180°$ The values of $f(\theta)$ from the approximate formulæ are shown plotted with the Klein-Nishina curves in Fig. 11 for the three wavelengths given above.

With these approximations the contribution to the scatter at a point from the parts of the medium which are above and below that point will be calculated separately.

The contribution to the scatter reaching the point Q from the disc AB of thickness δx (see Fig. 3) will be given by

$$KP_d e^{\mu_o x}\delta x \int_{\theta=0}^{\theta=\cos^{-1}x/R} e^{-m\frac{(\sigma_a+\tau)_\theta}{\cos\theta}} (A + B\cos^2\theta)\tan\theta d\theta$$

$$= KP_d e^{\mu_o x}\,\delta x\, Q(x), \text{ say}$$

$Q(x)$ is now in the form used by de Waard (1946) if ${}_m(\sigma_a + \tau)_\theta$ is reasonably constant in the region of wavelengths around 60 X.U. (see Fig. 2) and in this wavelength region $Q(x)$ can be integrated directly.

Let ${}_m(\sigma_a + \tau)_\theta = \mu_a$

and let $z = \mu_a x \sec\theta$

$$\text{Then } Q(x) = A\int_{\mu_a x}^{\mu_a(R^2+x^2)^{\frac{1}{2}}} \frac{e^{-z}}{z}\,dz + B(\mu_a x)^2 \int_{\mu_a x}^{\mu_a(R^2+x^2)^{\frac{1}{2}}} \frac{e^{-z}}{z^3}\,dz$$

$$= A\left\{\int_{\mu_a x}^{\infty}\frac{e^{-z}}{z}\,dz - \int_{\mu_a(R^2+x^2)^{\frac{1}{2}}}^{\infty}\frac{e^{-z}}{z}\,dz\right\} +$$

$$B(\mu_a x)^2\left\{\int_{\mu_a x}^{\infty}\frac{e^{-z}}{z^3}\,dz - \int_{\mu_a(R^2+x^2)^{\frac{1}{2}}}^{\infty}\frac{e^{-z}}{z^3}\,dz\right\}$$

An integral of the form $\int_x^\infty \frac{e^{-u}}{u^3}\,du$ can be expressed in terms of $\int_x^\infty \frac{e^{-u}}{u}du$, so that $Q(x)$ can be evaluated using tables of the exponential integral $E_1(x)$ $\left(= \int_1^\infty \frac{e^{-xu}}{u}\,du = \int_x^\infty \frac{e^{-u}}{u}\,du\right)$

Recently, however, Placzek (1945) has drawn up tables of the numerical values of $E_n(x)$ $\left(= \int_1^\infty \frac{e^{-xu}}{u^n}\,du\right)$ for values of n from 0 to 20, and this makes the computation of expressions of the form $Q(x)$ very much less laborious.

Since $\int_x^\infty \frac{e^{-u}}{u^n}\,du = \frac{1}{x^{n-1}} \times E_{(n)}(x)$, $Q(x)$ can be written in the form

$$Q(x) = A\left\{E_1(\mu_a x) - E_1(\mu_a\sqrt{R^2+x^2})\right\} +$$

$$B(\mu_a x)^2\left\{\frac{E_3(\mu_a x)}{(\mu_a x)^2} - \frac{E_3(\mu_a\sqrt{R^2+x^2})}{\mu_a^{\,2}(R^2+x^2)}\right\} \quad \ldots\ldots (4)$$

With Placzek's tables $Q(x)$ can be evaluated for any form of $f(\theta)$ which can be expressed as $\Sigma A_n \cos^n\theta$, for n up to 20.

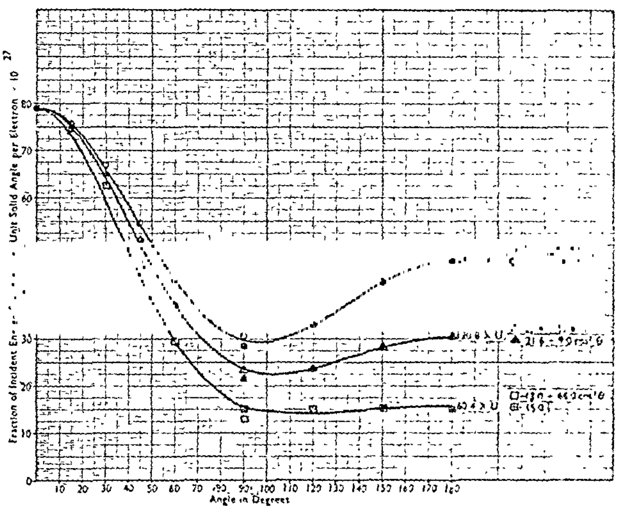

FIG. 11.

Empirical formulæ used to express the Klein-Nishina scattering function.

Integration of $Q(x)$ when μ_a is a linear function of wavelength

The expression $Q(x)$ can be integrated directly not only when ${}_m(\sigma_a+\tau)$ or the particular absorption coefficient used is a constant, but also when it is a linear function of wavelength.

Let ${}_m(\sigma_a + \tau)_\theta = \mu_a + k.\triangle\lambda$

where μ_a is the value of ${}_m(\sigma_a + \tau)$ for the primary radiation and $\triangle\lambda$ is the increase in wavelength after scattering through an angle θ and k is a constant.

Now, by Compton's theory, $\triangle\lambda = \frac{h}{mc}(1 - \cos\theta)$

so that ${}_m(\sigma_a + \tau)_\theta = \mu_a + \frac{kh}{mc}(1 - \cos\theta)$

The exponential term in the expression for $Q(x)$ will now be

$$e^{-x\sec\theta\left\{\mu_a + \frac{kh}{mc}(1-\cos\theta)\right\}} = e^{-x\sec\theta\left(\mu_a + \frac{kh}{mc}\right)} \times e^{\frac{xkh}{mc}}$$

which is equivalent to increasing the real absorption coefficient for the primary radiation by the constant quantity $\frac{kh}{mc}$ and multiplying the whole expression by the factor $e^{\frac{xkh}{m}}$.

This extension of the method is of value in enabling single scattering calculations to be done since the total absorption coefficient for water $_m(\sigma_a + \sigma_s + \tau)$ can be taken as a linear function of wavelength with reasonable accuracy over the range from 80 X.U. to at least 250 X.U.

Expression for total scattered radiation at a depth

The total intensity of scattered radiation at a point Q at a depth d from parts of the medium above Q is given by

$$I_d\ (\text{forward}) = KP_d \int_{x=o}^{x=d} e^{\mu_o x}\, Q(x)dx$$

A similar expression will hold for the scatter from the parts of the medium below Q, with $\mu_o x$ having a numerically negative value.

Having evaluated $Q(x)$ using the exponential functions the integration with respect to x must in general be carried out graphically unless the calculated values of $Q(x)$ are expressed as an exponential or sum of exponentials. However, for certain special cases the integration can be performed directly, using the general expressions for $Q(x)$.

The expression for $Q(x)$ (equation 4) can be rearranged thus:

$$Q(x) = A.E_{1(\mu_a x)} + B.E_{3(\mu_a x)} - \left\{A.E_{1(\mu_a\sqrt{R^2+x^2})} + \frac{Bx^2}{R^2+x^2} E_{3(\mu_a\sqrt{R^2+x^2})}\right\}$$

The first two terms represent the value of $Q(x)$ for an infinite field:

$$\overset{\infty}{Q}(x) = A.E_{1(\mu_a x)} + B.E_{3(\mu_a x)} \quad \ldots\ldots\ldots\ldots (5)$$

The total forward scatter at the given point, for an infinite field, is then given by

$$\overset{\infty}{I}_{d(forward)} = A.K.P_d \int_o^d e^{\mu_o x}\, E_1(\mu_a x)dx + B.K.P_d \int_o^d e^{\mu_o x}\, E_3(\mu_a x)dx$$

These integrals can be evaluated using the recurrence relations for $E_n(x)$ and integrating by parts.

A table of integrals involving $E_n(x)$ has been drawn up by Le Caine (1945), which is of considerable value in this type of calculation.

The integration leads to a value for $I_d^{\infty}{}_{(forward)}$ of

$$K.P_d \times \frac{1}{\mu_o}\left\{(A + Bp^2)e^{\mu_o d} E_1(\mu_a d) + Bpe^{\mu_o d} E_2(\mu_a d) + Be^{\mu_o d} E_3(\mu_a d) + (A + Bp^2)\, E_i[\mu_a d\,(\tfrac{1}{p} - 1)] - (A + Bp^2)\log(\tfrac{1}{p} - 1) - \frac{B}{2} - \frac{B}{p}\right\}$$

where $p = \frac{\mu_a}{\mu_o}$ and $E_i(z) = \int_{-\infty}^{x} \frac{e^z}{z}\,dz$

Values of $E_i(z)$ are given in tables (1940) published by the Federal Works Agency, Works Project Administration (New York).

The correction for finite focal distance in this method of calculation is that made by using the modified value for μ_o, as previously described.

The total scatter received at the given point from points in the medium below it is given by an expression similar to equation 5 with the appropriate values of A and B. $\mu_o x$ has a numerically negative value and the limits of integration are from 0 to ∞. The final expression is simpler than in the case of the forward scattered radiations and has the form

$$I_{d\ (back)} = KP_d \times \frac{1}{\mu_o}\left\{(A^1 + B^1p^2)\log(1 + \tfrac{1}{p}) - B^1p + \frac{B^1}{2}\right\}$$

where A^1 and B^1 are the values of A and B for $f(\theta)$ from $\theta = 90°$ to $\theta = 180°$, and p again has the value $\frac{\mu_a}{\mu_o}$.

For those wavelengths where $f(\theta)$ is a constant for the backward scattered radiation, *i.e.*, $B^1 = 0$, $I^{\infty}{}_{(back)}$ has the simple form $KP_d.\frac{A^1}{\mu_o}\log\left(1 + \frac{\mu_a}{\mu_o}\right)$

Value of $Q(x)$

The complete graphical integration of $\int_o^d e^{\mu_o x}Q(x)dx$ introduces some uncertainty since $Q(x) \to \infty$ as $x \to 0$. This difficulty can be avoided, however, as the integral can be solved directly for small values of x.

The integral involved in the expression for the contribution of scattered radiation from all discs within a small distance x_1 above the chosen point is $\int_o^{x_1} e^{\mu_o x}Q(x)dx$ and this can be shown to be equal to $x_1\left\{Q(x_1) + A\right\}$ for small x_1.

This very simple result can be applied with sufficient precision for $x_1 = 0{\cdot}5$ cm. for most of the calculations described in the present investigation.

PLAIN RADIOGRAPHY OF THE SKULL IN THE DIAGNOSIS OF INTRACRANIAL TUMOURS

By David Stenhouse, M.B., F.R.F.P.S., D.M.R., Major R.A.M.C.

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THE first radiological demonstration of an intracranial tumour was made by Obici and Bollici (1897). Radiography has since then been used in increasing measure in the diagnosis of these cases, and now is carried out almost routinely in neurosurgical units. Prior to the introduction of ventriculography by Dandy (1918), plain radiography of the skull was the only method available. Since then, interest in it has been rather overshadowed by the remarkable localising accuracy of the newer technique. Plain radiography, however, is still important, because it can give information not only about the site of a tumour, but about its pathological nature. Moreover, it requires no special skill and can be carried out as part of the routine investigation of suspected cases of intracranial tumour in a general hospital, and for that reason should be of wider interest than pneumography. On these grounds the present analysis was considered justifiable.

Various opinions have been expressed as to the diagnostic accuracy of plain films. Crouse (1923) stated that 8 per cent. of cases of brain lesions can be diagnosed from the röntgenogram. Dandy (1923) said that 15 to 20 per cent. of brain tumours could be localised by calcification and local destructive changes. In 1927 Sosman said that in the main groups of tumours (*i.e.*, gliomas, pituitary adenomas, suprasellar cysts, meningiomas and acoustic neuromas) which made up 88 per cent. of the 1146 verified cases in Cushing's series, it was possible to identify the tumour in 37 per cent. by the straight films alone. Johnson and Hodges (1943), in a series of 565 cases observed between 1931 and 1941, found a localising accuracy of 24 per cent. In the present series, 30·5 per cent. showed signs on the straight films which were considered to be of localising value; and signs of increased intracranial tension were found in 22·5 per cent.

Material

The cases forming the present series number 200. All were admitted to the Glasgow and West of Scotland Neurosurgical Unit at Killearn Hospital during the period April 1942 to April 1946, and all conform to the following criteria:—

1. Histological verification of the diagnosis.
2. Site of tumour verified at operation or post-mortem
3. Previous X ray of skull.

The incidence of the various types of tumour is shown in Table I.

TABLE I

Incidence of Intracranial Tumours from 1942 to 1946

Type of Tumour	Number of Cases	Percentage Incidence
Extracerebral:		
Pituitary Adenoma ..	16	8
Neurinoma	12	6
Meningioma	24	12
Osteoma	5	2·5
Chordoma	1	0·5
Craniopharyngioma ..	6	3
Intracerebral:		
Glioblastoma	43	21·5
Astrocytoma	39	19·5
Oligodendroglioma	2	1
Medulloblastoma	2	1
Ependymoma	6	3
Pinealoma	4	2
Blood vessel tumours ..	7	3·5
Congenital tumours ..	2	1
Colloid cyst	1	0·5
Papilloma	1	0·5
Mestastases	19	9·5
Tuberculoma	10	5
Total ..	200	

The division into extracerebral and intracerebral groups is useful from the radiological point of view because the former group, being in relatively close contact with or arising from skull, may be expected to give a higher percentage of localising signs. In the extracerebral group, localising signs were found in 37 out of 64 cases, or 57·8 per cent. For the intracerebral group the corresponding figures were 24 out of 136, or 17·6 per cent.

The changes which may be found on plain films in cases of intracranial tumour are commonly classified as localising signs and signs of increased

intracranial tension. In parts of the skull other than the sella turcica it is generally possible to place a given abnormality emphatically into one or other of these two groups. But in the sella, there are certain abnormal appearances which may be caused equally well by a local tumour and by increased intracranial tension. For this reason the sella turcica will be considered as a separate problem.

SELLA TURCICA

The sella turcica is a remarkably important structure from the radiological point of view. Among the structures of the base of the skull, it stands out most clearly on the X-ray film; and its appearance is liable to be altered by a wide variety of intracranial lesions.

As seen in the lateral film of the skull, the shape of the sella is rather variable within normal limits. These normal shapes have been described by Cairns and Jupe (1939) as oval, circular, and flat. Scheuermann (1932) is content to classify them into two types, oval and round, with a frequency of 46 per cent. and 54 per cent. respectively. Whatever names may be applied to these different types, it is sufficient to know that they exist normally, and that they should not be regarded as having pathological significance.

The size of the sella is another feature whose wide normal variations have been studied by a number of observers. Chaumet (1930) has recommended that the measurements should be made on the lateral film in two dimensions: the antero-posterior diameter being the distance from the tuberculum sellæ to the most distant point of the anterior wall of dorsum; and the depth being the distance measured at right angles from the mid-point of a line joining tuberculum sellæ and posterior clinoids, to the floor. In a study of 500 films of normal skulls, Camp (1930 (a)) found that the antero-posterior diameter varied between 5 and 16 mm., average 10·6 mm.; and the depth between 4 and 12 mm., average 8·1 mm. Pancoast (1940), in a comparable study, found that the maximum figure for the antero-posterior diameter was 12 mm. and for the depth 10 mm. From the point of view of measurement alone, unusual smallness of the sella has little importance. The problem generally is to assess whether or not in a given case the sella is abnormally large.

Abnormal appearances of sella were found in two groups of lesions: tumours in or near the sella, and tumours at a distance from it. These will be considered separately.

Tumours in or near the sella

These included chromophobe adenoma, suprasellar cyst, suprasellar meningioma, glioma of chiasma and optic tract, and chordoma. The sellar changes found in this group might be classified as thinning of dorsum only, erosion of dorsum only, erosion of dorsum and floor, and enlargement with or without thinning of dorsum. The incidence of these changes in the various types of tumour is shown in Table II. In addition, two of the suprasellar cysts showed calcification. Thinning of dorsum

TABLE II

TUMOURS IN OR NEAR SELLA

	Pituitary Adenoma	Suprasellar Cyst	Suprasellar Meningioma	Glioma of Chiasma or Optic Tract	Chordoma
Normal appearance	1	3	—	1	—
Thinning of dorsum	—	—	—	2	—
Erosion of dorsum	—	1	1	—	—
Erosion of dorsum and floor	1	—	—	—	—
Enlargement	14	2	—	—	1
Calcification	—	2	—	—	—
Number of cases	16	6	1	3	1

is the term used when the radiographic density of the dorsum as seen in the lateral view was considered to be less than normal. When the dorsum, in whole or in part, was not visible in the lateral view, the term erosion is used. For the purpose of this classification, a sella was considered to be enlarged when the antero-posterior diameter and depth exceeded 12 mm. and 10 mm. respectively. In three cases, owing to complete erosion of dorsum, it was not possible to measure the sella and these are not included in the enlarged group. In two cases, erosion of dorsum was confined to the upper part only.

Tumours distant from the sella (metasellar tumours)

Changes in the sella may be found when the brain tumour is situated at a distance. It is generally considered that in these cases the sellar changes are

associated with increased intracranial tension. The incidence of sellar changes in metasellar lesions is given in Table III.

TABLE III

Sellar Changes in Metasellar Lesions

	Number of Cases	Number with Sellar Changes	Percentage
Supratentorial lesions	116	27	23·1
Infratentorial lesions	57	14	24·5
Total ..	173	41	23·7

The difference in incidence of sellar changes between the supratentorial and infratentorial groups is less than might be expected, in view of the greater tendency of infratentorial tumours to cause increased tension by blockage of aqueduct. Thinning of dorsum was found in 27 of all the metasellar lesions, and erosion in 14. None of the sellæ which showed thinning of dorsum was measurably enlarged. In the cases showing erosion of dorsum it was not possible to measure the sella, so it cannot be said definitely whether any of these was enlarged or not.

In the case of tumours in or near the sella, alterations in the sella are produced by the direct pressure or invasion of the tumours themselves. The mechanism of the production of sellar changes in metasellar lesions is more intricate. Most observers agree that there is an association with increased intracranial tension: and that the greater the tension and the longer its duration the more likely is there to be destruction of the sella. The tension must be applied equally to the whole of the inner surface of the skull. But the dorsum sellæ shows the effects soonest, probably because it consists largely of cancellous bone and, projecting unsupported into the cranial cavity, it is subjected to inexorable pressure from all sides.

Besides increased tension, other factors may be involved. Some observers, including Scheuermann (1932) and Cairns and Jupe (1939), have indicated that destruction of dorsum and enlargement of sella may be caused by the pressure of a dilated third ventricle. Another feature which may accompany increased intracranial tension and which may be detected radiologically is hydrocephalus. It was therefore considered worth while finding out whether in metasellar lesions there was any correlation between:—

1. Degree of hydrocephalus.
2. Relationship of anterior end of third ventricle to the sella.
3. Degree of destruction of dorsum sellæ.

As a preliminary it was thought desirable to use some method of expressing the degree of hydrocephalus by measurement rather than by general terms such as slight or advanced. For this purpose the encephalographic ratio, as described by Evans (1942), was adopted. The measurements, which are made on the antero-posterior film of the pneumographic series, are the distance between the lateral margins of the anterior horns of the lateral ventricles, and the greatest distance between the inner table of the vault on each side. The ratio of the first to the second is the encephalographic ratio.

In order to assess the normal range of the ratio with the technical factors used in this unit, 50 cases were chosen in which encephalography had been carried out for the investigation of epileptiform fits and which were ultimately proved to have no space occupying lesion. In these the average ratio was 0·28, with minimum and maximum figures of 0·25 and 0·32 respectively. The figures are higher than those of Evans, whose minimum and maximum values were 0·20 and 0·25. The difference may be accounted for by the fact that the present group, although the nearest approach to normal that was obtainable, had suffered from epilepsy and may therefore have had mild degrees of atrophy. The values are probably on the generous side of true normal.

The encephalographic ratio was assessed in 71 cases of metasellar tumour in which air studies had been carried out. The relationship between the size of the ventricles and the degree of sellar absorption is shown in Table IV.

TABLE IV

Relationship Between Degree of Hydrocephalus and Degree of Sellar Absorption in Metasellar Tumours

	Metasellar Tumours with no Sellar Change	With thinning of dorsum	With erosion of dorsum
Number of cases ..	53	11	7
Minimum enceph. ratio	0·23	0·33	0·33
Maximum enceph. ratio	0·51	0·48	0·58
Average ratio ..	0·31	0·38	0·46

The numbers are small, but the average figures suggest that hydrocephalus and sellar absorption run parallel courses. But the hydrocephalus is not the direct cause of the sellar changes, because there were several cases in which marked hydrocephalus existed with a normal sella, and some in which there was complete erosion of the sella with little or no hydrocephalus.

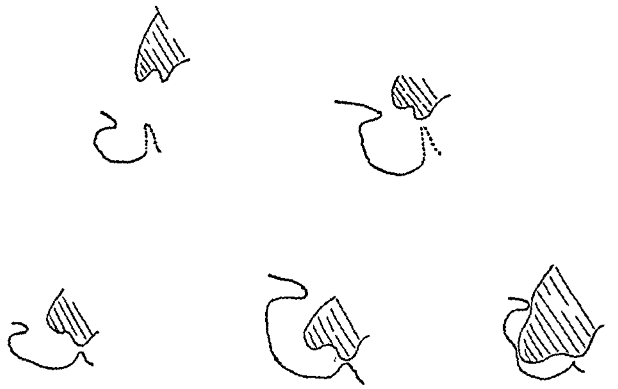


Fig. 1.
Tracings from ventriculograms of metasellar lesions, showing the variable relationship of anterior end of third ventricle to sella, and the degrees of destruction of dorsum.

In pneumograms, the relationship between the anterior end of the third ventricle and the sella may be seen in the lateral brow-up projection. This relationship was examined in 14 cases of metasellar lesions in which ventriculography had been carried out and in which sellar changes were present. Tracings of some of these cases are reproduced in Fig. 1. Eight of the cases showed thinning of the dorsum, and in all of these the anterior end of the third ventricle lay well above the sella. Six showed varying degrees of erosion of the dorsum, and in these the anterior end of the third ventricle was resting on the dorsum or actually invading the sella in a manner which suggested that it might well have been at least a contributory cause of the erosion.

Differential diagnosis of sellar changes

An examination of the sellar changes found in the present series suggests that only in a minority of the cases can the appearances be regarded as localising evidence. Fig. 2 shows two examples of asymmetrical erosion of the floor of the sella caused by chromophobe adenoma and chordoma respectively. Uniform enlargement with little or no thinning of the dorsum (Fig. 3) is almost certainly due to an intrasellar lesion. Finally, suprasellar calcification (Fig. 4) is reliable evidence of a lesion in that situation.

The majority of sellar changes, however, consist of thinning or erosion of the dorsum, and these may be caused equally well by local tumours or by tumours at a distance (Figs. 4 and 5). In these cases the diagnosis must be made clinically or by pneumography.

Fig. 2.
Asymmetrical erosion of sella caused by (*a*) chordoma, and (*b*) chromophobe pituitary adenoma.

Signs of Increased Intracranial Tension

Increased intracranial tension, when it has existed for some time, may produce changes in parts of the skull other than the sella turcica. The most familiar of these changes are starting of the sutures and increased convolutional markings.

Starting of the sutures was found in six cases, all of them children below the age of ten years. Four

of these cases were caused by tumours in the posterior fossa and two by tumours above the tentorium. This sign, of course, is not found above the age of about fifteen years, when the sutures begin to unite.

On the inner surface of the vault of the skull, and in the anterior and middle fossæ, there are normally a series of ridges and hollows corresponding with the convolutions of the cerebral hemispheres. In increased intracranial tension the abnormally high pressure of the brain pulsating against the inner wall of the skull causes resorption of bone, so that the hollows become deeper and manifest themselves on the X-ray film as the so-called beaten silver appearance (Fig. 6). In adults this appearance need not be very marked to be significant. In the present series it was found in one adult, a woman of thirty-two years, who had a cerebellar astrocytoma. In children, on the other hand, the convolutional markings are normally quite pronounced, and the change must be gross before it can be taken into account. Three children showed this appearance, and all of them had starting of the sutures as well.

FIG. 3.
Uniform enlargement of sella due to chromophobe pituitary adenoma.

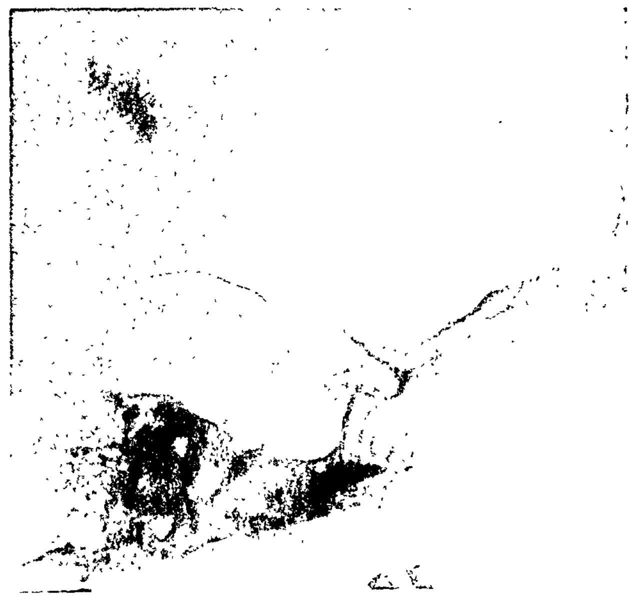


FIG. 4.
Amorphous calcification in a suprasellar cyst. There is also erosion of dorsum sellæ.

There appears to be some difference of opinion as to the possible effects of increased tension on the diploic channels. Jefferson and Stewart (1928), and Lindblom (1936), have stated that they tend to become less prominent in these cases; whereas Cairns and Jupe (1939) say that they become larger. It is doubtful whether the radiological appearance of the diploic channels is of much value in these cases, because the normal variability in size is such that, in order to be certain that a change has occurred, any individual case would have to be observed over a period of time.

A sign to which Lindblom (1936) has drawn attention is increase in size of the occipital emissary foramina. These vary in number from one to four, and in size, according to Lindblom, up to 2 mm. normally. Only three cases of the present group showed significant enlargement of the occipital emissary foramina (Fig. 10).

One other radiographic sign which may be due to increased intracranial tension is lack of definition of the lesser wings of sphenoid, as seen in the postero-anterior view with 20 deg. tube tilt towards the feet. This is referred to in connection with sphenoidal ridge meningiomas.

The value of all of these signs of increased intracranial tension is limited by the following considerations:—

1. They are common to all cases of increased tension, and not only to those caused by brain tumour.
2. The increased tension must have existed for some time, probably at least six months, before the signs become detectable.
3. Even when they are present, and are due to tumour, they give no indication of its site.

Localising Signs

The Pineal Shift

The pineal gland may become calcified and may then be demonstrated on an X-ray film. Normally it occupies a certain fixed position within the skull. Displacement outside of that normal limit may be taken as evidence of a lesion within the cranium, either a space-occupying lesion on the side opposite the direction of shift, or an atrophic lesion on the same side.

The frequency of calcification of the pineal was assessed by Dyke (1930), who examined 3000 skull films, at 51 per cent. Vastine and Kinney (1927) found 47·9 per cent. of 616 skulls to have calcification of the pineal. In the present series 54 cases (*i.e.*, 27 per cent.) showed definite calcification of the pineal. Of these, displacement was detected in 24.

The detection of lateral shift is comparatively easy. The most suitable projection for the purpose is the occipital. The pineal is more or less centrally placed on the antero-posterior diameter of the skull, and a slight degree of rotation of the head due to faulty positioning should not cause an appreciable error in measurement. In spite of this it is desirable, especially when the lateral shift is small, to avoid rotation as far as possible. The presence of a lateral shift is estimated by measuring the distance of the gland from the inner table on each side.

Shifts in the sagittal plane, that is in the vertical or antero-posterior diameters, are more difficult to estimate, because there are so many possible landmarks from which to make the measurements, and because there is a certain normal variation in the position of the pineal in this plane. Vastine and Kinney (1927) were the first to study this problem. Using lateral films of normal skulls, they measured the distance of the calcified pineal from the inner table of the frontal bone, inner table of occiput, inner table of vault, and the base of skull. From these measurements they constructed charts showing the normal variation in pineal position. Dyke (1930) criticised their results on the grounds that he frequently found in normal skulls pineals lying anterior to their normal zone, which he said should be moved forward 2 mm.

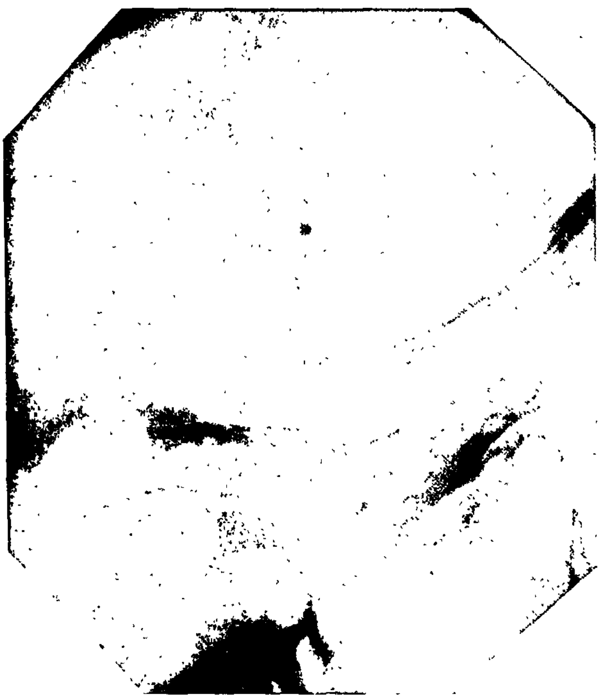


Fig. 5.
Complete erosion of dorsum sellæ due to a parietal lobe glioma.

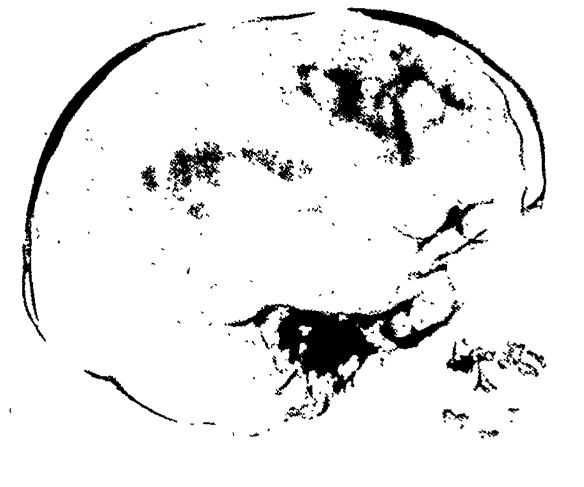


Fig. 6.
Increased convolutional markings and starting of the sutures in a case of cerebellar astrocytoma.

The disadvantage of Vastine and Kinney's method is that it involves two steps, the measurements on the film and the consulting of charts. Certain observers, using Vastine and Kinney's figures for their normal limits, have devised mechanical means of making the process more rapid and less liable to human error. Fray, for example, has invented two modifications (1937 and 1938). One depends on

stretching between the inner tables of frontal and occipital bones an elastic cord on which markers indicate the normal pineal zone for both the antero-posterior and vertical diameters. The second makes use of two strips of cellulose on which angles are marked. One strip is used for estimating antero-posterior displacement and the other for vertical displacement. When they are applied to the lateral film of the skull in a specified manner the normal pineal should fall within the angles.

The method of assessing sagittal shift which I have used is that of Allen (1940). A full description will be found in Allen's article. Briefly the method consists of the use of two unexposed developed 10 by 8 in. films. On these are ruled parallel lines indicating the normal limits of the pineal, as estimated by Vastine and Kinney, for the antero-posterior and vertical diameters respectively. The films are cut in such a way that, when they are applied to the lateral film of a skull, it is possible to find points on opposite edges which will exactly coincide with the greatest antero-posterior or vertical diameters of the skull being examined. The normal pineal should then fall within the parallel lines. Dyke's modification of moving the anterior limit forward by 2 mm. was adopted.

Schuller (1918) was the first to draw attention to the fact that the pineal may be displaced to the opposite side by a tumour in the cerebral hemisphere, or to the same side by brain atrophy. Naffziger (1925) reported several cases in which lateral shift of the pineal was a help in localising a brain tumour. The incidence of lateral and sagittal shifts, and their significance, will be considered separately.

Lateral Shift

The density of calcification of the pineal may be such that it is visible in the lateral view, but not in the antero-posterior. The existence of a lateral shift cannot of course be detected unless the pineal can be seen in the antero-posterior film. In this series, 32 were visible in the antero-posterior view. Of these, 13 showed a lateral shift which in every case indicated a tumour in the hemisphere opposite to the direction of shift. A larger number, 15 in all, showed no lateral shift. The absence of a lateral shift might be predicted on the following theoretical grounds:—

1. Tumour situated in the posterior fossa.
2. Tumour in one cerebral hemisphere too small to produce a detectable shift.
3. Multiple tumours in both hemispheres acting, as it were, with equal and opposite forces.
4. Small supratentorial midline tumours.

This is substantiated by an investigation of the tumours showing no lateral shift. They comprised eight infratentorial tumours, one very small tumour in left basal ganglia, two cases of multiple metastases, and four sellar or suprasellar lesions.

Saggital Shift

Shifts in the sagittal plane are more difficult to measure, but they are important because the pineal is more often visible in the lateral than in the antero-posterior view. Vastine and Kinney (1927) found in 163 cases of verified brain tumour with calcified pineal, 51 per cent. of the gliomas and 59 per cent. of the meningiomas showing a shift. Lilja (1934) examined 60 cases of verified brain tumour in whom the pineal was calcified, and found that 23·3 per cent. showed a shift in the sagittal plane. He stated that none of the infratentorial tumours caused a shift.

In this series, 15 cases showed a sagittal shift. All were supratentorial, and in each the direction of shift was away from the tumour. Pituitary lesions caused an upward shift, frontal lesions backward, occipital lesions forward and parietal lesions downward. However, the rule that the displacement is away from the tumour does not appear to be infallible. Hawes and Mead (1943) described three cases of infratentorial tumour in which the pineal was displaced posteriorly. This they ascribed to the pineal being carried backwards by the dilated posterior end of third ventricle.

No sagittal shift was discovered in 39 cases. The reasons for the negative findings were found to be the same as those enumerated for lateral shift. And there appeared to be one additional factor, namely, remoteness from the sagittal plane. Eight cases in which the tumour was large enough to cause a lateral shift showed no shift in the sagittal plane. In each of these the bulk of the tumour was situated near the surface in the temporal or lower parietal regions.

There were five cases which showed a shift in both the coronal and sagittal planes. These gave the most accurate localising evidence of all, since it was possible to tell not only which hemisphere was involved, but roughly which part of it. For example,

a right lateral and backward shift suggested a tumour in the left frontal lobe.

CALCIFICATION

Calcification within the cranium may be found normally in the pineal, choroid plexuses, falx, arachnoid, and clinopetrous ligaments. It may occur in old hæmorrhages or in abscesses. This discussion will be limited to a third type of calcification, that which may be found in brain tumours.

Weed (1914), in a microscopic study of 55 brain tumours, found evidence of calcification in 40 per cent. But the frequency with which calcification may be detected radiologically is much less. It was described first by Strom (1919), who estimated the frequency at 6 per cent. Camp (1930 (b)), in a series of 781 verified lesions of brain seen at the Mayo Clinic, found radiographic evidence of calcification in 7·6 per cent. In the present series it was found in 14 cases, *i.e.*, 7 per cent. They comprised two meningiomas, two astrocytomas, four osteomas, three suprasellar cysts, one oligodendroglioma, one dermoid, and one hæmangioma.

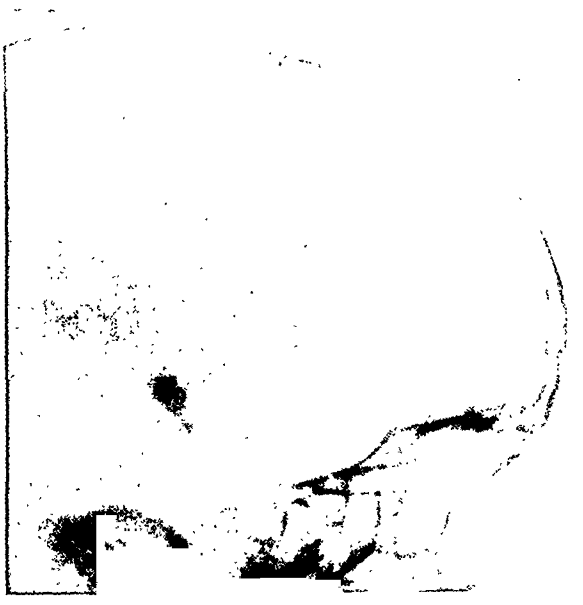


FIG. 8.
Dermoid showing calcification in the shape of a tooth.

FIG. 7.
Dense homogeneous opacity with lobulated outline, typical of osteoma.

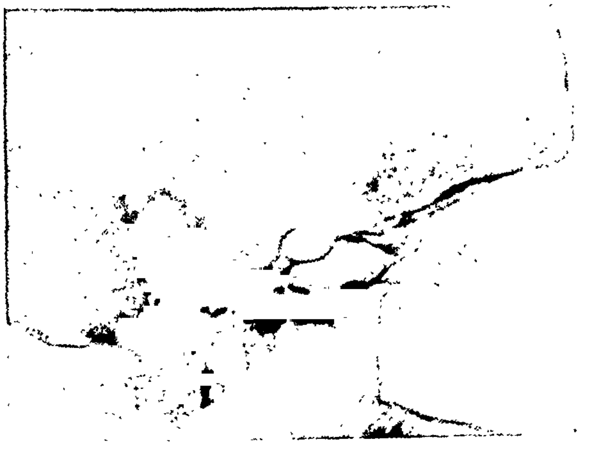


FIG. 9.
Stippled calcification in a hæmangioma.

In only two types of tumour was it possible, because of the appearance of the calcification, to make a reasonably accurate pathological diagnosis: in certain of the osteomas, because of their attachment to the base of skull, their extremely dense homogeneous opacity, and their sharply defined lobulated outline (Fig. 7); and the dermoid, because the calcification was in the shape of a tooth (Fig. 8).

In the other cases the appearance of the calcification was not specific. For example, a meningioma and a hæmangioma both showed a fairly well-defined mass of stippled calcification, strikingly similar in appearance (Fig. 9). And a cerebellar astrocytoma showed a sharply defined shadow with a dense crenated margin and stippled interior (Fig. 10), an appearance which has been described by Evans and Courville (1938) and Martin (1937) as being frequently found in tuberculoma. Each of the three examples of suprasellar calcification, as in most cases

reported in the literature, was found to be a craniopharyngioma. But even this cannot apparently be regarded as diagnostic, because Dale (1934) has reported calcification in this situation in chiasmal glioma and in suprasellar meningioma.

Indeed, with the two exceptions named above, the series illustrates the principle, pointed out by Dale and others, that the radiographic demonstration of calcification gives reliable evidence of the presence and position of a tumour, but not of its nature.

Bone Erosion

Because of their position relative to the skull, the extra-cerebral group of tumours have one common property capable of being demonstrated radiographically, namely, erosion of bone. Pituitary tumours have already been discussed under sella turcica.

Chordomas are rare tumours. Hass (1934) reported one case and reviewed 56 chordomas of skull and cervical spine collected from the literature. Only one example is included in the present series. When first seen the X-ray findings consisted of slight erosion of one half of the sella, and destruction of the buttress of bone between the optic foramen and the sphenoidal fissure on the same side. On both clinical and radiographic grounds the case was considered to be one of aneurysm of internal carotid, and carotid ligature was carried out. After a temporary improvement the patient's condition deteriorated, and further radiographic examination a year later showed that the destruction of bone was considerably more advanced, there being marked enlargement of one half of the sella, erosion of the lesser wing of sphenoid, and destruction of one anterior clinoid (Figs. 2a and 11). At operation a large extradural tumour was found, which was shown by histological examination to be a chordoma.

Fig. 10.

Calcification in an astrocytoma in posterior fossa. Note also dilated vascular markings and enlarged emissary foramina.

Erosion of bone is a fairly frequent accompaniment of acoustic neuromas. Studies of the radiological signs to be found in these cases have been made by Cushing (1917), Mayer (1930), Schuller (1928), Stenvers (1928), and Towne (1926). It is not always easy to demonstrate the internal auditory canal. A number of projections may be used. They have been enumerated and evaluated by Ebenius (1934). The most generally useful is the occipital, which shows both canals on one film and simplifies comparison. This projection was used in the first instance in all cases; in some, when the canals could

not be identified with certainty owing to superimposed shadows, the Stenvers projection was helpful.

Acoustic neuromas are of slow growth, and it is generally thought that the erosion is due to pressure by the tumour itself. Pancoast (1928) has suggested that in some cases the pressure may be exerted by a lateral sinus distended because of occlusion by the neighbouring tumour. The radiographic signs to be expected from the position of the tumour are enlargement of the auditory canal with or without erosion of petrous ridge. Ebenius (1934) has found that there may exist in normal cases a difference in diameter of 1 to 3 mm. between the right and left auditory canals, and that a simple expansion of the canal must be marked before it can be regarded as significant. He suggested that a more reliable sign was a funnel-shaped deformity of the canal, produced by a greater relative expansion of the orifice.

In the present series there were 12 acoustic neuromas. Localising signs were found in 6. Three showed erosion of the apex of the petrous, 2 showed a funnel-shaped enlargement of the internal auditory canal (Fig. 12), and 2 showed simple enlargement.

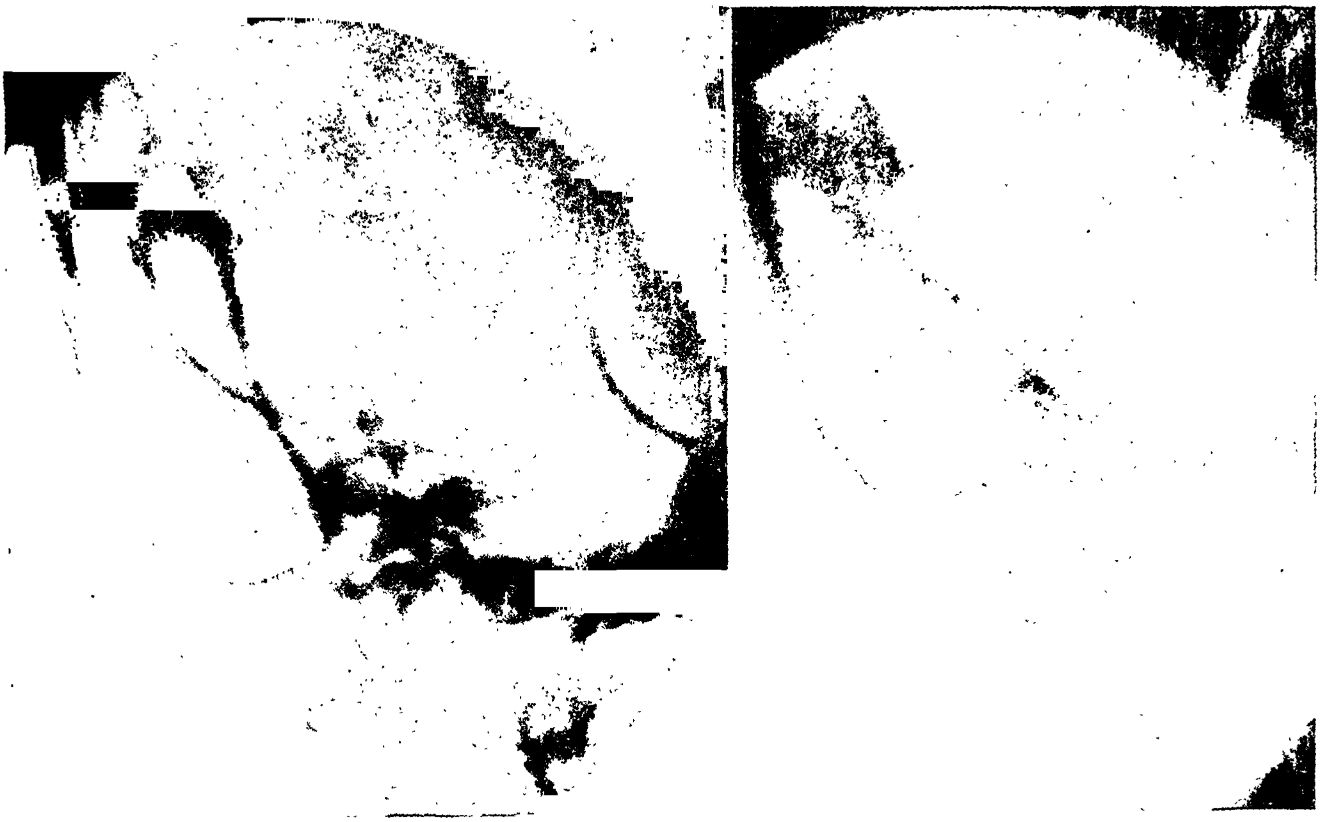
It is well known that erosion of bone may be caused by meningiomas. The erosion may be slight or marked and it may be combined with new bone formation. Any part of the skull may be involved, but basal tumours appear to be more liable to cause erosion than tumours in contact with the vault. In the base, erosion may be difficult to demonstrate radiologically. In the present series, 2 of the meningiomas caused bone erosion. One affected the petrous ridge and the other the lesser wing of sphenoid.

Meningiomas of the sphenoidal ridge present a particularly difficult problem in X-ray diagnosis. The most satisfactory projection for showing the sphenoidal ridges is the postero-anterior with 20 deg. tube tilt to the feet. They appear in this view as narrow triangular areas of increased density crossing the shadows of the orbits. When bone has been eroded by a meningioma, one of the shadows becomes less distinct than its fellow. I have found, however, that this sign cannot always be regarded as localising evidence. In the whole series of 200 tumour cases there were 8 in which one or both sphenoidal ridges appeared indistinct in the postero-anterior view. Only one of these could be attributed to erosion by meningioma. The others were tumours in various parts of the skull, both above and below tentorium; the only feature common to all of them was increased intracranial tension. It seems possible therefore that in some cases increased intracranial tension may cause erosion of one or both sphenoidal ridges. In a series of 23 cases of meningioma of sphenoidal ridge, David (1933) found erosion on the side of the tumour in 5 and on the opposite side in 3. Pancoast (1940) points out that absence of the shadow of lesser wing may occur on one side as a normal variant.

Fig. 11.
Specimen of chordoma, showing marked enlargement of sphenoidal fissure. (Same case as in Fig. 2 (*a*).)

The conclusion appears to be that in the postero-anterior view, diminished density on one side of the sphenoidal ridge cannot be taken as reliable evidence of the presence of a sphenoidal ridge meningioma. In the case already referred to, the interpretation was relatively easy, because erosion was not confined to the lesser wing. The greater wing was clearly involved also, and there was marked enlargement of the sphenoidal fissure (Fig. 13).

the meningioma cells migrate through the dura into the vascular spaces of the bone, where they set up an osteoblastic reaction; the tumour cells may ultimately penetrate into the scalp. Kolodny (1929), on the other hand, suggests that the hyperostosis is initiated by a slow vascular dilatation, set up by anastomoses between the dilated meningeal vessels supplying the tumour and the veins of the diploœ; and that the result of the invasion of tumour cells,



A · B

Fig. 12.

Funnel-shaped enlargement of left internal auditory canal due to acoustic neuroma (*b*). The normal right side is included for comparison (*a*).

which takes place later, is bone erosion, progressing sometimes to the stage of complete perforation of skull. In the sections which he examined he found that new bone formation was taking place most intensively at the periphery of the hyperostosis, where in radiographs dilated diploic channels are sometimes seen.

According to Cushing (1922), the hyperostoses are seen most frequently in the sagittal region of the vault. He states that the size of the bony swelling is not necessarily commensurate with that of the

New Bone Formation

While bone erosion is a sign that is common to all of the extracerebral group of tumours, new bone formation appears to be the prerogative of the meningiomas. The association between meningiomas and cranial hyperostosis was first described by Spiller, Sterne, and Kirkbride (1899). Since then several detailed reports have appeared in the literature.

Histological studies made by Cushing (1922), Phemister (1923), and Penfield (1923) indicate that

underlying tumour. It evidently depends more on the area of contact. Thus a large spherical tumour with but a small area of attachment to the membranes will produce a small hyperostosis; whereas the plaque-like growths may have large hyperostoses associated with them.

FIG. 13.
Meningioma causing erosion of lesser wing of sphenoid and enlargement of sphenoidal fissure.

From the radiological point of view, lesions of the vault are generally easy to detect and interpret. The swelling is smooth in outline and often involves the whole thickness of the skull. In its outer part, radiating spicules are a frequent finding. In early cases the change may be confined to a small projection on the inner table, demonstrable only by tangential views.

Bony reactions to basal meningiomas are radiologically more difficult. Because of the normal complexity of the bony structure in this region they may not be easy to detect. Furthermore, the reaction is not so likely to be a swelling as a diffuse bony overgrowth, easily confused with diseases of bone, such as osteoma or osteitis fibrosa.

In this series, 2 of the meningiomas had produced hyperostoses. Both were in the vault. The first case showed a smooth swelling in the right frontal region, extending from the midline over an area of about 5 cm. in diameter, and involving the right frontal sinus. The swelling was not high, the projection above the normal surface being less than a centimetre. It did not rise steeply, but merged smoothly into the surrounding normal bone, forming a small arc of a large circle. Tangential views showed that the whole thickness of the vault was involved, that the tables could not be distinguished from one

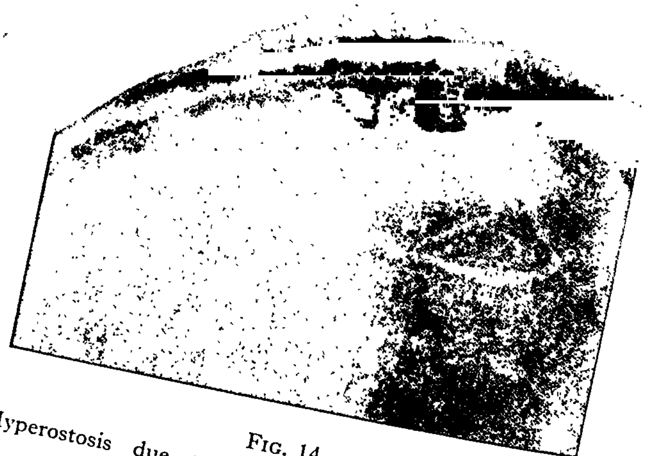


FIG. 14.
Hyperostosis due to meningioma. The neighbouring meningeal grooves are dilated.

another, and that although the thickness of the bone was increased, its radiographic density was less than normal. Radiating spicules were not seen in this case.

In the second case, situated in right parietal parasagittal region, the hyperostosis was more remarkable. It rose abruptly from the surrounding bone to a height of $1\frac{1}{2}$ cm., its outline was smooth, and its diameter was 6 cm. Tangential views showed that the whole thickness of the vault was involved, that there was an associated but smaller internal hyperostosis, and that the inner and outer tables were still distinguishable from one another. It was also seen that the external part of the hyperostosis contained fine spicules radiating perpendicularly to the outer table (Figs. 14 and 15).

Very similar appearances to those described above may be found in a number of conditions affecting bone primarily. Examples are metastases, sarcoma, osteitis deformans, von Jaksch's anæmia, osteitis fibrosa, and hæmangioma. Two cases were recently admitted to Killearn Hospital for investigation of bony swellings of skull possibly secondary to intracranial tumour. One proved to be osteitis fibrosa and the other hæmangioma. In each case the radiographic appearance of the bony swelling bore many points of resemblance to those produced by the meningiomata. There were two differentiating features: The sides of the swellings were relatively steep, and the outer tables were involved to a greater degree than the inner.

It would appear therefore that the hyperostosis produced by a meningioma may be closely imitated in its radiographic appearance by certain other lesions of bone. But if, in any given case, there is clinical or pneumographic evidence of an intracranial tumour corresponding in position to that of the bony swelling, then the tumour may safely be regarded as meningioma rather than any other of the primary brain tumours.

VASCULAR MARKINGS

The vascular channels which may become dilated in the presence of intracranial growths are the meningeal vessels and the diploic veins.

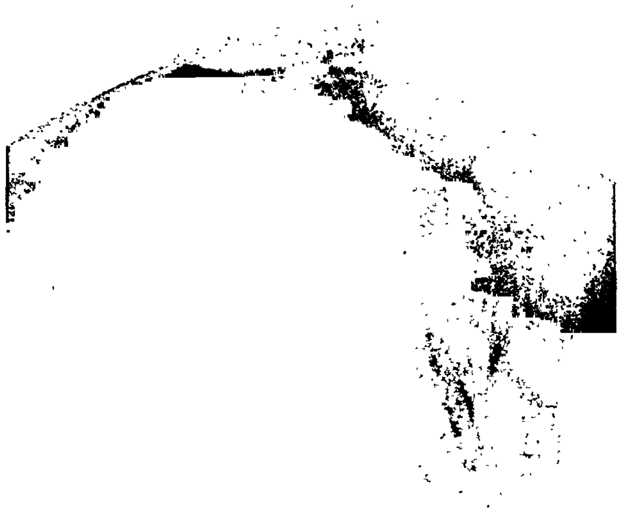


FIG. 15.
Same case as in Fig. 14. Soft tissue projection to show the radiating spicules.

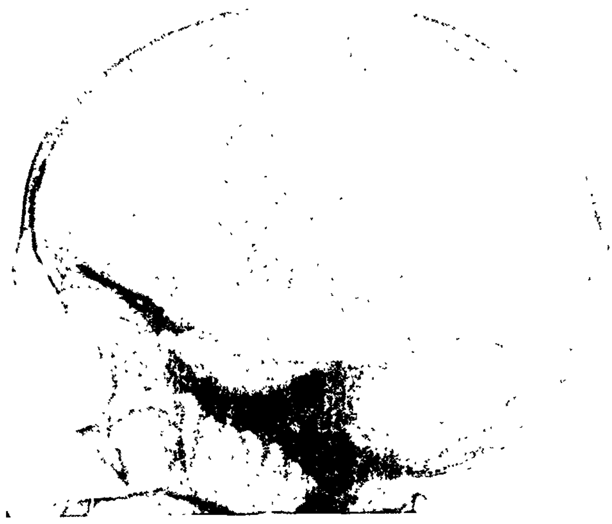


FIG. 16.
Meningioma showing gross dilatation of diploic channels. The meningeal grooves are enlarged to a lesser degree.

The meningeal arteries, accompanied by meningeal veins, run in grooves in the inner table of vault. Their size and distribution are quite constant in normal cases and they are easily seen in the lateral film of skull. The meningeal vessels supplying a surface tumour such as a meningioma or arterio-venous aneurysm may in the course of time become dilated. This dilatation manifests itself radiologically as an increase in the width and tortuosity of the bony channels in which the vessels run. The appearances have been described by Sosman and Putnam (1925), and David, Marcel and Stuhl (1933). As Lindblom (1936) has pointed out, the foramen spinosum on the affected side may also become widened. In the present series, 3 meningiomas showed definite widening of the meningeal grooves in the neighbourhood of the tumour (Fig. 14).

The diploic markings are a less reliable index than the meningeal grooves, because of their extreme normal variation in size and distribution. Some observers, including Elsberg and Schwartz (1924), have indicated that enlargement of the diploic channels at the convexity may signify underlying meningioma. But the value of this sign has been questioned by Jefferson and Stewart (1928), LeWald (1924), and Kornblum (1935). There was only one case in the present series, a meningioma, in which

the dilatation of the neighbouring diploic channels was so gross as to be considered significant (Fig. 16).

Conclusions

Plain radiography of the skull may be competently carried out with the equipment available in the average general hospital. The proportion of positive findings is high enough to justify its use in every case suspected of having a brain tumour. In about a fifth of all cases of brain tumour, radiographic signs of increased intracranial tension may be expected. While these may be caused by lesions other than tumours, their discovery may suggest that further special investigation is necessary. Signs indicating not only the presence but the approximate position of a brain tumour are found in about a third of all cases. Negative findings in the plain films of skull do not exclude the existence of an intracranial tumour.

Acknowledgments

I am indebted to Dr. C. K. Stevenson for permission to publish this paper; and to Mr. J. E. Paterson and Mr. J. Sloan Robertson for their valuable help and advice.

Summary

1. An analysis has been made of the plain radiographic findings in 200 verified cases of intracranial tumour.

2. Sellar changes were found in two groups of lesions: tumours in or near sella, and tumours at a distance from it (metasellar lesions). Of all the abnormal sellar appearances, only two were considered to be of localising value: uniform expansion with little or no thinning of dorsum, and suprasellar calcification. The commonest changes were thinning or erosion of dorsum, and these were common to both groups of lesions.

3. In metasellar lesions showing sellar changes, the degree of sellar destruction and the degree of hydrocephalus are roughly proportionate to one another, but the hydrocephalus in itself is not the cause of the bone destruction. In some of these cases, however, the dilated anterior end of third ventricle comes into close contact with sella, and it is suggested that this may be at least a contributory cause of the sellar changes.

4. Signs of increased intracranial tension, comprising starting of sutures, increased convolutional markings, widening of the occipital emissary foramina, and thinning or erosion of dorsum sellæ, were found in 22·5 per cent. of all cases.

5. Localising signs were found in 30·5 per cent. They included pineal shift, calcification, bone erosion, new bone formation, and widening of the vascular channels.

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A SIMPLE APPARATUS FOR MAKING RAPID SERIAL RADIOGRAPHS OF SMALL OBJECTS

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THE apparatus to be described has been developed in connection with some work that the writer, in collaboration with Dr. E. W. Walls, has been carrying out on the circulation of the frog using radiographic methods. Although designed for this special study the apparatus appears to possess certain features of more general interest, and the following account has therefore been prepared.

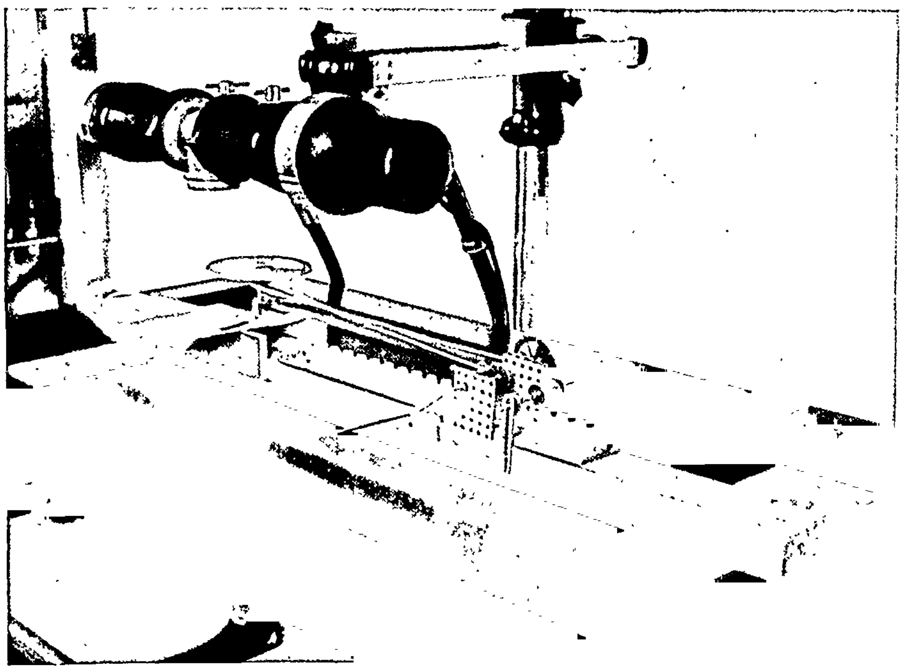
In their preliminary study of the circulation of the frog Foxon and Walls (1947) used a method of pushing cassettes through a lead tunnel under the experimental animal and so made serial radiographs at intervals of a few seconds. However, it was decided that more frequent pictures were desirable; if possible, several during one heart beat. This matter was discussed at some length with Dr. A. E. Barclay, of the Nuffield Institute for Medical Research. For various technical reasons Dr. Barclay advised against the use of either of the methods of cine-radiography used by him and his colleagues in their classical work on the fœtal circulation. These methods, termed "direct" and "indirect" cine-radiography, have been described by Barclay, Franklin and Prichard (1940). Dr. Barclay kindly invited Dr. Walls and myself to make use of a hand-operated tunnel in his laboratory which allowed radiographs to be made at approximately one per second. Unfortunately this speed again proved to be somewhat too slow. It was decided that a speed of at least three pictures per second should be aimed at.

The speed of three radiographs per second, which is much the same as that generally used by Dr. Barclay in his "direct" method (Barclay *et al.* 1940), would enable about six pictures to be taken covering the course of one cardiac cycle in the frog where the heart rate may, at normal room temperature, be expected to vary between thirty and forty beats per minute. Now it was realised that with a heart beating at this rate, so long as the picture was kept small, several heart beats could be recorded at the desired speed on a strip of film some 18 in. to 2 ft. in length. Thus a roll of film was not essential for this purpose; it would be sufficient to move a strip of film under the subject at the required rate. One of the difficulties mentioned by Dr. Barclay in the paper already quoted is that of operating the necessary switchgear at the requisite speed, and so timed that the current passed through the tube at the moment the film was still. In the present instance there was no immediate possibility of altering the switching arrangements of the X-ray unit and it was decided to use a completely different method of making the exposures. This method is based on the fact that the tube available for this work could be used at radiographic intensities up to a maximum time of 8 seconds. Thus the principle of the apparatus is to use a continuous beam of X rays which is interrupted by a lead shutter while the film is moved onwards by intermittent motion in a lead-protected tunnel, the subject being placed on a window in the tunnel directly under the X-ray tube. The shutter is above the subject. It might be thought that an elaborate "set-up" would be required to ensure that the film is still while the shutter is open and also to move the film and shutter at the requisite speed, but, in fact, this is not so and the apparatus now in use was made up in the laboratory from old salvage wood and "Meccano" parts.

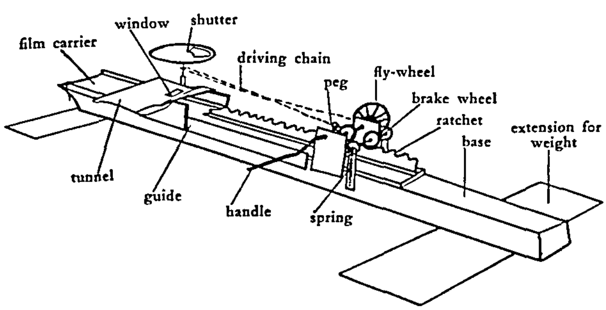
Description of Apparatus

The apparatus (Figs. 1A and 1B) consists of a base of wood $50 \times 3 \times 2$ in., the top of which is polished smooth to permit a thin piece of wood 38 in. in length to slide freely upon it; this latter piece will be called the film carrier. The base bears extensions upon which weights are placed to hold the apparatus steady in operation. At the sides of the base are small pieces of wood of suitable size to act as guides which ensure that the film carrier slides directly to and fro on the base. On the guides mounted sufficiently high to permit a clear passage of the film carrier is a lead tunnel. In this tunnel a window

has been cut, $\frac{7}{8} \times 2$ in. The necessary overall size of the tunnel to give protection to the film, other than that below the window, was determined by direct experiment. Only one half of the piece of wood which has been called the "film-carrier" is actually used for this purpose, the second half carries a firmly fixed notched ratchet, the notches so spaced that the straight front faces are exactly 1 in. apart. A peg attached to a turning handle engages in each notch in succession and thus the film-carrier moves forward 1 in. for each turn of the handle. As soon as the peg ceases to make contact with the ratchet the carrier stops and remains stationary while the peg makes the remainder of the revolution and then engages in the next notch; in this way the carrier is moved forward in a series of jerks. In order to make sure that the carrier does come properly to rest during each exposure a "brake" is applied to the top of the ratchet. This brake consists of a rubber-tyred "Meccano" wheel which is pressed on to the ratchet by means of springs. Each time the ratchet stops, the wheel presses firmly down into one of the notches. The next movement forward of the ratchet is therefore made against the pressure of the spring. The somewhat inclined face of the back of each



(A)



(B)

Figs. 1a and 1b.
Photograph of the apparatus set up under the X-ray tube with diagram indicating the various parts. The focus-film distance is 14 in. and the lead glass shield usually used on the tube has been removed for clarity.

notch ensures that the resistance of the brake is not too strong to be overcome.

At the end of the turning rod remote from the handle is a sprocket wheel which is used to drive a rotating shutter by means of an exactly similar sprocket wheel on the shutter spindle. The two wheels are connected together by a length of "Meccano" chain. The distance between the two sprocket wheels is about 20 in., which is sufficient to allow the chain to be twisted through an angle of 90 degrees and so the sprocket wheels rotate in planes at right angles to each other. Thus while a continuous turning of the handle imparts a continuous rotary motion to the shutter, it also gives an intermittent motion to the film-carrier. These principles are, of course, familiar in the ordinary cinematograph projector, but are there seen in a much more highly finished mechanical condition. The application of this principle to the particular problem in hand by means of home-made apparatus is, however, quite successful.

The following additional points should be noted. First, the shutter is of lead backed by aluminium mounted upon a spindle. The slit in the shutter subtends an angle of approximately 90 degrees and at the rate of three revolutions per second gives an exposure of approximately $\frac{1}{12}$-second. Secondly, the lead tunnel curves upwards as shown in the figure to allow the head of the ratchet to enter below it while the final frames of the sequence are taken. Thirdly, the films are double wrapped in black paper envelopes of light-tight construction which are firmly fixed to the carrier by means of adhesive tape.

The apparatus is hand driven, the requisite speed being attained by the operator turning the handle in time with a metronome beating at the desired speed. The even spacing of the frames is largely dependent on a steady turning of the handle, to assist which a small fly-wheel has been attached to the turning handle.

At present the apparatus has been operated for periods of 5 seconds at a time using standard X-ray film 15×12 in., cut into strips 15×2 in. The speed of the machine has been three exposures per second; thus for each 5-second exposure of the tube fifteen frames have been produced, which is sufficient for the present purpose.

It would seem that the apparatus could be modified in various ways to suit other purposes; for example, by driving the carrier by an inverted

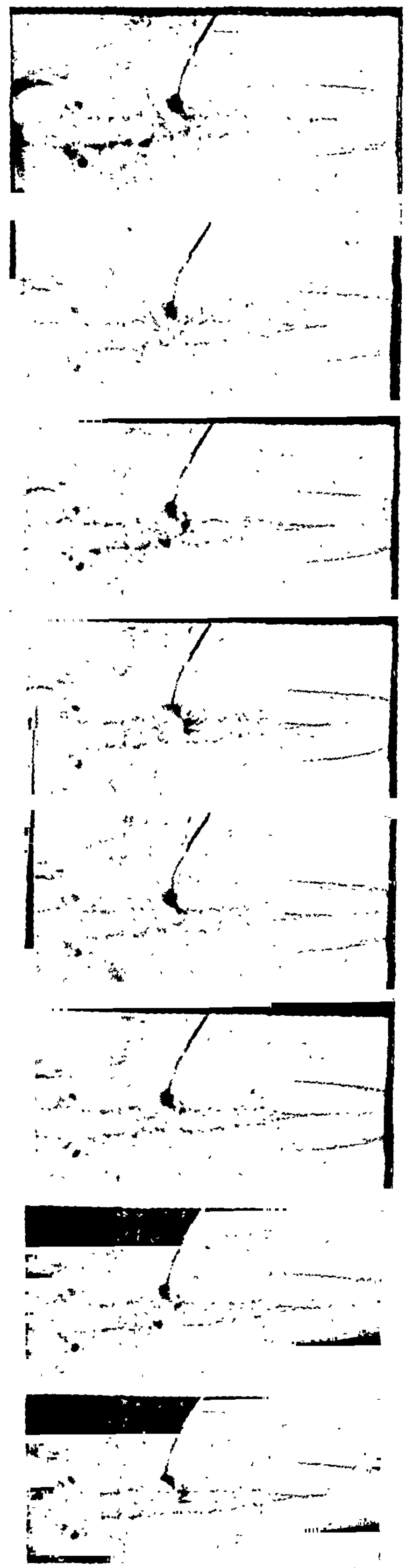


FIG. 2.
A series of radiographs taken with the apparatus described. The series is to be read from left to right; for full description see text.

ratchet working below, it would be possible to use the whole length of the carrier for conveying the film, thus allowing more frames to be taken. Again, if the somewhat crude ratchet I have used were replaced by some properly designed intermittent motion gear, such as a "geneva mechanism", a much higher speed of operation would be possible, and then the exposure time for each frame would probably become the limiting factor. A more adequate driving mechanism would allow of some considerable increase in the size of frame.

To summarise, it may be said that the disadvantages of this type of rapid serial radiography lie in (1) the limits imposed on the size of individual frames, (2) the total length of the film, which being flat limits the number of frames, (3) the longest permissible exposure period of the X-ray tube at radiographic intensities. On the other hand the advantages are (1) the apparatus is portable and can be used with any suitable X-ray tube, (2) no modifications are necessary to existing X-ray apparatus, (3) cheapness and ease of construction, (4) a very surprising reliability in use.

Fig. 2 shows some consecutive frames from a strip of film taken with the apparatus. The film shows an injection of the radio-opaque medium "thorotrast" into the pulmonary vein of a pithed frog. The subsequent passage of the thorotrast through the heart, which is still beating, can be seen. The significance of these radiographs will be discussed elsewhere. The following points may be of interest. Time between each frame, $\frac{1}{3}$-second. Focus-film distance, 14 in. Tube, Philips Metalix, 6 kW. No screens were used, the kilovoltage was 43 and the milliamperage 30.

ACKNOWLEDGMENTS

I have to express my best thanks to Professor C. M. West, of the Department of Anatomy, University College, Cardiff, for allowing me radiographic facilities in his department; also to Dr. A. E. Barclay for the kind invitation to visit his department and use apparatus there as has already been mentioned. I also desire to thank Mr. A. Welch for technical assistance during the course of the work recorded here and for the photograph which forms Fig. 1A.

SUMMARY

An apparatus is described which permits of serial radiographs of small fields being made up to a rate of three per second. The apparatus is home-made and simple in construction. The principle of the apparatus is to use a continuous beam of X rays which is interrupted by a shutter placed above the object being radiographed; while the shutter is closed a film placed below the object moves forward and then becomes stationary while the next exposure is made. Suggestions for further applications of this principle are made.

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SYMPOSIUM ON THE GENETICS OF CANCER

A SYMPOSIUM on the Genetics of Cancer, organised by the Genetical Society of Great Britain and the British Empire Cancer Campaign, is being held in June of this year at the following times and places:—

Thursday, June 24, 10 a.m., Royal Society of Medicine, 1 Wimpole Street, W.1. "Inheritance of Cancer in Animals.'

Thursday, June 24, 2.30 p.m., Medical Society of London, 11 Chandos Street, W.1. "Virus and Carcinogen induced Mutations."

Friday, June 25, 10 a.m., Royal Society of Medicine, 1 Wimpole Street, W.1. "Virus and Carcinogen induced Mutations" (continued) and "Inheritance of Cancer in Animals" (continued).

Friday, June 25, 2.30 p.m., Royal Society of Medicine, 1 Wimpole Street, W.1. "Inheritance of Cancer in Man".

A number of American, European and British scientists will read papers. The meetings will be open to all interested in the subject.

SOME ASPECTS OF RADIOLOGY IN WAR-TIME GERMANY

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FROM the co-ordinated reports of a team of highly trained investigators who followed the Allied armies into Germany, the writer has been able to present some of the lines along which developments there in technique have taken place.

The information was made available by the British Intelligence Objectives Sub-Committee.

War placed an iron curtain between Britain and Germany. During that time, many of us must have speculated on how radiology was developing in the latter country. New innovations should take place, certain trends should be accelerated, and some developments in Britain would not mature there.

X-ray stereo-fluoroscopy

Orthodox X-ray fluoroscopy suffers from the disadvantage of presenting only a two-dimensional image. The Germans used two systems for X-ray stereo-fluoroscopy which permitted immediate stereoscopic vision and eliminated the delay of developing films and later viewing them in a mirror stereoscope. The advantage of seeing living movements in three dimensions, and not as two dimensional stills, is obvious.

Siemens-Reiniger introduced an apparatus which incorporated a pair of X-ray tubes and a fluorescent screen. The two X-ray tubes were displaced horizontally and parallel to a line through the two eyes of the observer. The X-ray tubes were in such a circuit that each one operated on alternate half-cycles of the 60 cycle A.C. power. A shutter was synchronised with the 60 cycle variations and turned in such a way before the observer's eyes that when the left tube was operating the right eye would see the fluoroscope, and when the right tube was operating the left eye would see the image. Very good stereoscopic effects were obtained by this method.

The Wiegelmann apparatus was even more ingenious than the Siemens-Reiniger. It employed two X-ray tubes which were mounted above the patient, a fluorescent screen and mirror mounted below the patient. The operator wore a pair of special spectacles fitted with vibrating shutters synchronised with the alternating current supplying the pair of X-ray tubes. The effect of the swing shutters was that the light of only one tube affected each eye. This occurred alternately fifty times per second, and through this action an image which did not flutter was perceived on the fluorescent screen *via* the mirror. The spectacles were light enough to be worn by the operator. Wiegelmann's apparatus was especially valuable for orthopædic surgery. Many orthopædic operations were performed using this method. It should be of value in cardiology, diseases of the chest, gastro-enterology, etc. It has been suggested that Wiegelmann's device should be of value in other fields such as coloured stereo-cinematography.

Photo-röntgenography

The routine size film used in miniature radiography was 35 mm. which gave a picture size of 24×24 mm. Although practically no new X-ray equipment was marketed during the war, developmental work did not cease. Siemens-Reiniger Werke were working on 80 mm. photoröntgen apparatus which used automatic timing. This film gave a picture size of 69×69 mm. The larger size offered the convenience of directly examining the negative whereas the smaller one required enlargement, preferably by projection.

The most popular apparatus was the transportable (35 mm.) one developed by the Siemens-Reiniger Werke and Zeiss-Ikon (Dresden). The optical system was the Zeiss-Sonnar. The lens had a focal length of 5 cm., an f. number of 1·5, and its inner surfaces were coated with an evaporated fluorite to reduce internal reflections. Its resolving power was approximately 15/1000 mm. The negative of 24×24 mm. was practically edge sharp. The lens system was an excellent compromise between sharpness of the image and light intensity, as an increase of light intensity, as a rule, requires simultaneous decrease of the sharpness. Film cassettes were used which could be exchanged in daylight.

Non-inflammable fluorapid film was the generally used photographic material, the sensitivity of which was adjusted to the green light of the superastral screen. This screen was a zinc-cadmium-sulphide

one with a specially smoothened surface which afforded sharp definition.

The optical systems, screens and films were designed to have characteristics which mutually compensated for each other. This gave rise to considerable improvement of contrast and definition.

Miniature radiographs could be projected to a size of 90×90 mm. on a surface within a light tunnel with sufficient intensity of light to make convenient examination in a moderately lit room possible. For copying purposes, the light tunnel was closed and a photo cell was automatically switched on which determined the exposure time required for copying. A lever would be lowered and a light sensitive paper automatically pulled down from a stock roll. This light sensitive paper slid over the picture platform and simultaneously the correct exposure was effected. When the lever was reversed, the paper was automatically guillotined and dropped into a stock-box. On opening the light tunnel, the apparatus was all set for further examination.

Zeiss introduced the Roentgensonnar lens with an f. number of 1·5 and a focal length of 10 cm. This lens had its inner surfaces coated to reduce internal reflections. The sharpness depicted by this lens was approximately twice as good as other German lenses of the same power. The negative size was 67×67 mm. and later 69×69 mm. with complete sharpness.

Dr. Christensen, a Danish physician, employed a mirror-optical system with an f. number of 0·6 calculated according to the system of Schmidt by the Danish astronomer, Lorenzen. Zeiss concentrated on these optical systems. They used spherical planes which could be manufactured on normal grinding machines, whereas, formerly, a correction plate, which could only be ground or retouched by hand, was employed. Zeiss claimed that they attained the same intensity of light but doubled the sharpness.

During the war great strides were made in the development of the Schmidt optical system in Britain. The applications of this system in this island were mainly in non-medical fields. The technique of *plastic* optical equipment was brought to a high degree of perfection in Britain. The great advantage of plastic over glass is that it becomes economically possible to adopt surfaces other than spherical and so a large aperture system free from aberration became possible. It may be argued that the plastic method requires a suitable mould and that this is quite as difficult as making a glass lens of the same shape, but one mould can be used for making many plastic lenses and with bulk production, the proportionate cost per lens is small. The tarnished lens system to reduce internal reflections was used in many fields of the British optical industry. The experience we have gained during the war can now be advantageously applied to photo-röntgenography.

X-ray constant potential generator

The Müller company successfully used, since 1938, a triode valve tube not only for high voltage switching but also for converting a condenser discharge wave-form into constant potential to the X-ray tube. Because of the voltage regulation function the voltage drop across the valve had to be as high as 60 kV in some instances, and its anode had to have a heat dissipation comparable to that of an X-ray tube. The continuous rating of the tube was 300 watts and short time rating 50 kW for 0·2 second. The valve was protected against the effect of the X rays by a cylinder of lead around the central portion of the tube.

Siemens-Reiniger Werke also used a triode valve since before the war in its "Kodiaphos", but for switching purposes only. This firm built an experimental tube for voltage regulation as well as for switching purposes, but it was not used in production.

One of the most striking and complicated X-ray generators was the Müller "Maximus D" which was introduced in late 1938. This was a condenser discharge equipment with grid valve and grid control circuit so that it gave a true constant potential to the X-ray tube. The circuit of the machine used approximately twenty tubes of one kind or another, of which ten were at high voltage. The first machine of this type to be put in the field was installed at the 1500 bed Frankfurt City Hospital and had been in operation since 1939. A considerable amount of service has been required of this apparatus and some changes were made in its circuit during the seven years of working, but on the whole it has been successful. The triode valve itself gave very little trouble. The equipment was very popular and was used more than any other X-ray apparatus at this hospital.

Automatic timing

Franke did experimental work on the automatic timing of X-ray exposures. The method was an advantage in miniature radiography. Franke used an ionization chamber with tin-coated electrodes. The tin was desirable to get ionization characteristics at different voltages similar to the light intensity characteristics of the fluorescent screen. The chamber had the same dimensions as the fluorescent screen and was 1 cm. in thickness. It was located between the subject and the screen. The front plate of the instrument was made of cellophane coated with tin to the size and shape desired, a centre plate of cellophane and tin and a back plate similar to the front one but electrically connected to it. A bakelite sheet protected the front of the chamber, and the back was protected by its attachment to a stationary grid.

The response of the ionization chamber was controlled by an amplifier. This system automatically compensated for variation in line voltage, tube emission, chest thickness and density. Franke did little or no work with photo-electric cells as he preferred the ionization method.

X-ray protection

German Government regulations, dated May, 1943, specified that the amount of X-ray radiation reaching any person should be limited to 0·025 r per day on the reproductive organs and 0·025 r on other parts of the body.

In many respects, more attention was paid to X-ray protection than in these islands or the U.S.A. This is shown by the care given to protection in fluoroscopy. It was customary to have a 3 ft. high protected mobile stand (with a stool attached on which the radiologist sat), interposed between the patient and operator. In addition, the fluoroscopic screen frame was fitted with lead rubber side and bottom flaps. Apparatus was designed to prevent the X-ray beam from extending beyond the screen frame, *e.g.*, a Siemens military field unit had a mechanism for automatically adjusting the maximum shutter opening for screen to table distances. In numerous cases the fluoroscopic X-ray tube was placed at a greater distance behind the table top than on American tables (15 in. on the Pantoscope, 19 in. on the Aequoskop), with consequent increased radiation tolerance on the part of the patient's skin.

The mirror in Wiegelmann's stereo-fluoroscope permitted the path of the X-ray beam to be directed away from the operator and reduced the harmful effect of the rays to a minimum. This mirror device had also the advantage that the operator would see the fluorescent image at an angle very suitable for operative manipulation.

Dr. Robert Jaeger did research work in the investigation of protective shielding and in the development of indicators to measure stray radiations. He employed a small X-ray detector which could be placed at a suitable point in an X-ray laboratory. This instrument could be sent by post to hospitals and returned to the main laboratory for evaluation.

Conclusions and summary

Two methods of X-ray stereo-fluoroscopy, *viz.*, Siemens-Reiniger and the Wiegelmann apparatus were introduced. These were very interesting methods, especially Wiegelmann's with its swing-blind spectacles.

The routine sized film in photo-röntgenography was 35 mm. which gave a picture size of 24 × 24 mm.

Apparatus was developed using 80 mm. film which gave a picture size of 67 × 67 mm. and later 69 × 69 mm.

Lenses, viewing screens and films were designed with characteristics which mutually compensated for each other.

Fluorite tarnished lenses to reduce internal reflections were popular.

Zeiss introduced Schmidt mirror optical systems into photo-röntgenography. These should be of value especially in cineradiography.

British workers developed the plastic technique in relation to the Schmidt optical system but this was not used in photo-röntgenography. Latterly, they developed a process of giving a very hard smooth skin to these optical devices. This technique can be adapted to photo-röntgenography with a saving cost compared to the Zeiss method.

The grid-valve was successfully applied to X-ray potential generators in order to get a constant voltage.

The trends in German radiology were towards use of automatic methods, compensating devices, safety measures and fool-proof apparatus. Franke experimented with an ionization chamber method which automatically compensated for variation in line voltage, tube emission, chest thickness and density.

It is doubtful whether the war significantly contributed to the development of German radiology.

ACKNOWLEDGMENTS

The author gratefully acknowledges the help which he has received from the British Intelligence Objectives Sub-Committee, and especially that of H. Neubrunn.

For those who would like to pursue the matter further, the author would refer them to the Board of Trade, German Division, Technical Information and Foreign Documents Unit (incorporating B.I.O.S. Secretariat), and in particular to the following reports:

1. J.I.O.A., Final Report, No. 46. "Unclassified Data on the German X-ray Industry".
2. B.I.O.S., Final Report, No. 212. "Ultrasonic Research and Development in X-ray Equipment; Siemens Reiniger Werke A.G., Erlangen".
3. F.I.A.T., Final Report, No. 884. "Biophysics with Special Reference to Electro-biology".
4. J.I.O.A., Final Report, No. 52. "German Photogrammetric Equipment, Stereoscopic X ray, Automatic Camera Mount, 9-lens Cameras".

REVIEW

Chronic Structural Low Backache. By R. A. Roberts. H. K. Lewis & Co., London, 1947. 45s.

"The picture of this problem, obtained from the radiographical approach after going into the patient's life history and a considerable survey of the literature, has therefore been presented as a clinical entity, with the hope of a more unified medical attitude to all those who suffer from the incomplete adaptability of the low-back structures to human activities in the erect posture."

"Yet all these symptoms and signs may be found with the various end results of the low-back structure being overstrained; they belong to the one problem which, being structural, is primarily orthopædic. These end results are not independent; the 'flail-joint' instability of the defective neural arch can precipitate or aggravate herniations of the disc; both cause compensatory over-action of many muscles with resultant œdematous pressure on several nerves, and later adhesions and contractions; any of these can make articular surfaces irregular and stimulate osteophytic reactions; and so on."

The preceding extracts taken from the text in the second part of this book briefly explain the author's indications of what he has set out to prove. In this second part he criticises the unbalanced attitude of specialists who see in patients only such conditions which fall into their own particular speciality and when they fail to do this assume that the patient is a "wangler". The author, it would seem, by regarding the flail-joint instability of the defective neural arch as the essential cause for low back pain has fallen into the same trap. He does not give sufficient credit to the fact that low back pain can be due to many diverse causes and that in each speciality genuine cures have been produced by the appropriate treatment; in fact some of the results have been so good that the specialists have been unduly impressed, to the degree that they have become obsessed with the idea that their own treatment is the only one likely to be successful.

Bearing in mind these impressions much of the discourse in the second part of the book may be read by the practitioner with advantage. He may be a little puzzled by the statements "Thus arose the question as to what a 'March Fracture' really is. The answer is that it is not a fracture at all but only an optical illusion". When the reviewer read through the first part, which consists of histories of cases with radiographic illustrations, he found the text unconvincing, and was amazed to see so little reference to the topical damaged intervertebral disc as a cause for the "sciaticas" and "lumbagoes". The impression was given that the author had been away on foreign service and out of touch with medical literature which for the past few years has contained many contributions which attributed to the damaged disc practically all the aches and pains of that nature; the structural defects, such as the author describes, having only a significance because of the associated lesions.

Though the reading of case histories can be most interesting this series one found tiresome and uninteresting, and containing too many of the inaccurately described observations of untrained minds with which medical men are all too familiar. The author appears to anticipate this criticism, for in defence he states: "In the medical literature, one does not get the patient's story except 'censored' by the preconceived views which experts unavoidably develop after years in their own speciality. If any think the histories are inaccurate or exaggerated let them first obtain their own histories under the same conditions, where the patient speaks freely and willingly without fear of any resultant effect of so speaking". But surely he is thinking of men in the services.

The author gives in the histories accounts of operations for diverse pathological conditions such as hæmorrhoids, gastro-intestinal disorders, including appendicectomy of "retrocæcal appendix found with fæcolith in tip causing acute inflammation", ending with the statement "This is a case where most people would have *missed the diagnosis* with only routine antero-posterior and lateral views"—the diagnosis being a defect in the neural arch of the fifth lumbar vertebra. One found it difficult to relate many of the clinical observations with the radiographic findings of such defects, and perhaps due to the defective reproductions of the radiographs, one found it difficult to justify the line drawing interpretations of the radiographic appearances. Maybe there is some truth in the author's italicised concluding statement: "There is a strong case for a reconsideration of our attitude to these cases who suffer from our inability to comprehend the underlying pathological changes."

JAMES F. BRAILSFORD.

CARCINOMA OF THE DUODENUM

By K. MENDL, M.D.(Prague), D.M.R.(Lond.), and
C. H. TANNER, M.B., B.S.(Lond.), F.R.C.S.(Eng.)
Swansea General and Eye Hospital

MALIGNANT tumours of the duodenum are rare, constituting 1–2 per cent. of all intestinal carcinomas. There have been reported only about 400 proved cases in the literature.

The commonest site is in the region of the ampulla of Vater, where they usually obstruct the bile and pancreatic ducts and produce icterus very early in the course of the disease. They originate either from the common bile duct or duodenal mucosa. They are either polypoid adenocarcinomas protruding into the lumen and showing a filling defect or they may be constricting scirrhous carcinomas leading to duodenal obstruction.

The supra-ampullary and infra-ampullary carcinomas are usually of the infiltrating type causing annular constriction and later obstruction.

The stenosing supra-ampullary carcinoma cannot be distinguished from pyloric stenosis clinically. The stenosing infra-ampullary tumour shows clinical symptoms similar to pyloric stenosis except that the vomit contains bile and pancreatic ferments.

CASE REPORT

Mrs. W. H., aged 41, was referred for X-ray examination of gallbladder and gastro-intestinal tract with a history of pain across the upper abdomen and jaundice since middle of November 1946. Appetite was poor and there was frequent vomiting. She had lost one stone in weight during the last six weeks.

Examination revealed a thin, icteric female.

A mass was palpable in the right hypochondrium which was pear shaped and in the position of the gallbladder. This mass moved on respiration. To the inner side of it was a hard sausage-shaped mass deeper in the abdomen which was vertically placed and fixed.

She had clay-like stools.

Wassermann Reaction was negative.

No biliary calculi were visible.

Barium meal (Fig. 1) in January, 1947, showed an annular filling defect of descending portion of duodenum $2\frac{1}{2}$ in. long with irregular and rigid borders and obliteration of mucosal pattern. There was no obstruction; on the contrary, the stomach emptied quickly and there was pooling of barium in the duodenum distal to the lesion. The diagnosis of Carcinoma was made.

At operation in January, 1947, a large firm tumour was found in the second part of duodenum, adherent to the vena cava, which was inoperable. Gallbladder was distended. There were no secondary deposits found. A posterior gastro-enterostomy and a cholecystoenterostomy were performed.

FIG. 1

A fortnight later she was discharged without icterus and in good general condition.

X-ray examination in June, 1947, showed apart from a well-functioning gastro-jejunostomy an increase in narrowing of the upper part and complete stenosis in the middle of the neoplastic lesion so that the lower part could no longer be demonstrated.

On examination in November, 1947, her general condition was good, and she had gained 12 pounds in weight. She had been apyrexial since the operation and has at no time since been jaundiced. The duodenal

tumour was palpable and had grown larger. The liver was not palpable and there was no ascites.

When first radiologically examined this patient showed an advanced infiltrating type of carcinoma involving the upper two-thirds of the descending portion of the duodenum. As there was only a six-weeks history of jaundice the site or origin must have been in the supra-ampullary region whence the carcinoma has extended downwards beyond the ampulla.

Acknowledgment

We are indebted to Dr. T. J. Evans for his permission to publish this case.

Summary

A case of carcinoma of the second portion of the duodenum is recorded. Attention is drawn to the satisfactory temporary result of a palliative operation.

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CORRESPONDENCE

Ossifying Hæmatomata and Other Simple Lesions Mistaken for Sarcomata

Sir,

With your indulgence I should like to answer the criticism of your correspondents of my paper with the above title.

I cannot agree with the statement made by Dr. Ellis that "no final diagnosis can be accepted (*e.g.*, in the assessment of the value of a method of treatment) unless there is histological evidence", because in the majority of "tumours" of bone the accurate diagnosis is made without any attempt to secure histological evidence. The radiographic evidence of those tumours of bone due to faulty development, deficiency, traumatic and inflammatory influences being characteristic, is accepted in diagnosis and treatment. Why, therefore, must we consider diagnosis of some lesions incomplete without a histological examination? I have given substantial evidence elsewhere (*Proc. Royal Soc. Med.*, 1948, April) that the histology of bone tumours is very unreliable and of possible danger to the patient in many respects.

The above title of my paper did not permit me to enter into a discussion on all the simple lesions illustrated. It is unfortunate that Dr. Elkeles was unable to give any personal experience and by reciting the contents of a paper suggest that it was unknown, for though familiar with the excellent contributions of Caffey and his followers (see Brailsford, "The Radiology of Bones and Joints", 4th Edit., 1947, pp. 653-654) I prefer to regard Figs. 9-11 as illustrating an ossifying hæmatoma; because I am satisfied that the serial radiographic appearances of this and several other lesions which I illustrated are those of calcium deposited in extravasated blood which gradually goes on to ossification.

I indicated that these hæmorrhages occurred in several conditions, but I instanced scurvy in particular because we know subperiosteal hæmorrhage to be a characteristic feature of that disease. R. Hutchinson and A. Moncrieff record "The chief changes (in infantile scurvy) are in the neighbourhood of the bones. A section made across a limb at the site of a swelling shows that the periosteum is hypervascular, thickened and separated from the subjacent bone by a layer of partially organised blood clot. There is no sign of inflammation and no hard bone is found in the periosteum except in long standing cases". Serial radiographs of certain limbs in scurvy show subperiosteal lesions which are undoubtedly hæmorrhages undergoing ossification and later absorption. As I have shown, in certain case the subsequent ossification of certain hæmatomata is modified by the added factor of osteogenesis imperfecta (see Figs. 4 to 8), paralysis (see Fig. 13) and repeated trauma (Fig. 15). Surely Figs. 19 and 20 more closely resemble Caffey's Fig. 8 (*Amer. Journ. Roent.*, July, 1945). Because the bones do not show the characteristic radiographic features of the well-developed lesion of scurvy or syphilis these factors cannot be excluded. It is my experience that subperiosteal hæmorrhages in these conditions are seen in association with bones which appear otherwise radiographically normal and it is eminently desirable that this should be recognised for it permits of successful treatment. Even Caffey and Silverman record "We did not have the opportunity to make

early biopsies of the soft tissues and the bone *when they might have been more important*". In my opinion serial radiography permits of an interpretation of the early lesion (weeks before biopsy would be considered reasonable), which is superior to that of histology at a later date because of the relatively rapid resolution.

While acknowledging the value of Caffey's contributions we must realise that "Infantile Cortical Hyperostosis" is but a term which may be used by other workers to describe a number of conditions of dissimilar ætiology. If a lesion responds to a specific treatment I prefer to think of it as such, rather than to give it the name of a condition for which there is no known cure. This sentiment has been expressed by Matthew Arnold:

> Nor bring, to see me cease to live,
> Some doctor full of phase and fame,
> To shake his sapient head, and give
> The ill he cannot cure a name.

Alas, a growing feature in modern medicine.

Yours, etc.,

Birmingham. James F. Brailsford.

The Determination of Fœtal Age

Sir,

The estimation of the age of a fœtus presents one of the most baffling problems in the whole of Medicine. Particularly is this so in the case of the earlier specimens which are of vital academic interest and are of equal importance medico-legally in cases of abortion following rape or illicit intercourse. The following methods are used to determine fœtal age:

(1) *Date from a single act of coitus*

These cases are as rare as they are valuable. Allowing twelve hours for fertilisation they usually give a perfect estimate, but even here there is a snag—the fœtus may die several days before extrusion; evidence of this would be shrinkage or maceration, however.

(2) *Menstrual history*

Although there is reason to believe that fertilisation usually occurs during the first seven days after the last period, the fœtus may be a day or three-weeks old from the time of the first missed period. For this reason it is of no use for any fœtus under three months. Another pitfall is that a case which aborts at the 4th month will often hæmorrhage at the 2nd and 3rd months when normally a period would have occurred and the woman mistakes blood for menses. Again, the fœtus may have died some days before extrusion.

(3) *Size of fœtus*

Two measurements are used:

(*a*) Crown-rump of Mall.
(*b*) Crown-tip of great toe.

Of these the former is the more accurate owing to the disproportionate shortness of the lower limbs. But fœtuses vary in size as do adults—one might as well say that a man of 5 ft. was younger than a man of 6 ft., or, more absurdly, that a full-term baby of 6 lb. was younger than one of 12 lb. It is remarkable how generally these measurements have been accepted as the basis of giving fœtal age.

(4) *State of ossification*

In spite of the truth of Prof. A. H. Harris's dictum that "the times of appearance and of union of epiphyses vary as do teeth in their eruption", I maintain that more can be learnt of the age of a fœtus by study of its ossification than by any other means. Three methods are available:

(*a*) Section.

Guy and Ferrier describe the process in the case of the lower femoral epiphysis "Cut successive slices of cartilage . . . till a coloured point becomes visible in the milk-white cartilage in the form of a more or less circular light blood-red disc, much harder than the surrounding tissues. In decomposed bodies, however, the cartilage is a dirty yellow tint and the ossific point a dusky red".

At the risk of being dubbed a heretic, I would question some of the dates in that classic *Gray's Anatomy*; not enough latitude is shown, indicating that the material used was small in amount; this is not surprising in view of the tediousness of the process. What is surprising is the accuracy attained. Fig. 433 of the 29th Edition is correct and appears in the 9th Edition of 1880. The method, if necessarily aided by the microscope, is accurate—it was the only method available to the older workers.

(*b*) Clarified specimens.

An excellent collection of these was destroyed at the R.C.S. Museum, London, during a blitz. The fœtus is placed in 10 per cent. potassium hydrate until the whole, save the bones, is translucent, when it is placed in 10 per cent. Dettol or it may, with advantage, be stained. They are excellent for study; unfortunately, if not removed from the alkali at the right moment, they are liable to collapse.

(*c*) Radiology.

Though one sees radiographs of fœtuses from time to time, there has been, to my knowledge, only one systematic exploitation of this valuable aid, namely, Lambertz, whose illustrations are magnificent. Unfortunately they are of comparatively old subjects, which are not of the same interest as the early ones. One gets the impression that he dates them according to previous work and not "de novo". X rays reveal in a few minutes what other methods can only show after days or even weeks of preparation. I would suggest starting on a "clean slate", using

the following bones as key points, at least the initial date of six weeks for the clavicle and mandible, and the 10th lunar month for the lower femoral epiphysis rest on a solid foundation of truth. They are:

1. Mandible and Clavicle. The earliest to ossify—6th week.
2. Vertebral laminæ. Begins at atlas, working downwards—date uncertain.
3. Vertebral bodies. Begin about D.12, proceed upwards and downwards. After laminæ but date uncertain.
4. Ilium—about 8th week.
5. Ischium—about 3rd month.
6. Pubis—about 5th month.
7. Os Calcis—about 6th month.
8. Astragalus—about 7th month.
9. Lower femoral epiphysis—10th lunar month.

As regards material, there is ample among the general practices of the country. If they could be induced to send examples together with notes, these key bones could soon be dated. As regards the appearance of centres of ossification and their unions there is ample material already in any large hospital without the necessity of taking a single special radiograph.

FIG. 1.
Clarified specimen.

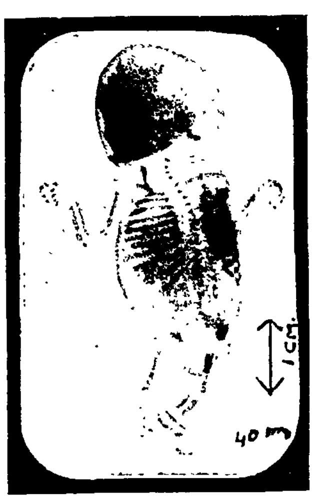

FIG. 2.

Illustrated (Fig. 1) is the photograph of a clarified specimen and a radiograph of the fœtus (Fig. 2). The latter is about natural size.

I should like to have readers' opinions regarding the age of this fœtus. Notable is the absence of ossification of the vertebral bodies and the comparatively limited ossification of the pelvis.

Yours, etc.,

Dumfries. A. P. BERTWISTLE.

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WILLIAM MORTON ROBSON, M.D., F.R.C.P.

SIR,

The retirement of a medical man because of age limit brings with it, to his colleagues and friends, recollections of his past activities and achievements.

Now that a third and fourth generation of radiologists come into the front line, it is proper to honour those among the pioneers of medical radiology who attained a high standard in their work and by deed contributed long ago to the speciality, and brought about the recognition of radiology as an essential discipline in medical science.

Dr. Robson took up radiology at the beginning of the century, and in 1905 started building up a radiological service at the General Hospital, Northampton. He devoted his time, as most of the radiologists of the first era, to both diagnosis and therapy. Working in times when the foundations of radiology were laid, Dr. Robson indirectly contributed to the sifting of the sound from the unproven. To a sound judgment and a penetrating sagacity he joined a boundless enterprise and adamantine constancy of purpose. A first rate clinician (he acted as Honorary Physician to the Hospital for over two score of years), he could not fail as a radiologist. His diagnostic work was excellent, and in therapy of benign and malignant conditions his results may appear astonishing considering the technical means and theoretical data available.

A distinguished man with great personal charm, he is universally liked and respected. At meetings of the Röntgen Society he was listened to with attention, great weight being laid upon his remarks.

Dr. Robson has not completely abandoned medical work, but now that he has severed his relation with practical radiology, the wish might be expressed that he may long enjoy his retirement and witness the development in a branch of medicine which he took up at a time when the hazards and risks attached to it were already known well.

Yours, etc.,

Northampton. B. JOLLES.

INDEX OF CURRENT RADIOLOGICAL LITERATURE

Titles marked with an asterisk have been abstracted for ABSTRACTS OF WORLD MEDICINE, and of SURGERY, OBSTETRICS AND GYNÆCOLOGY, published by the British Medical Association.

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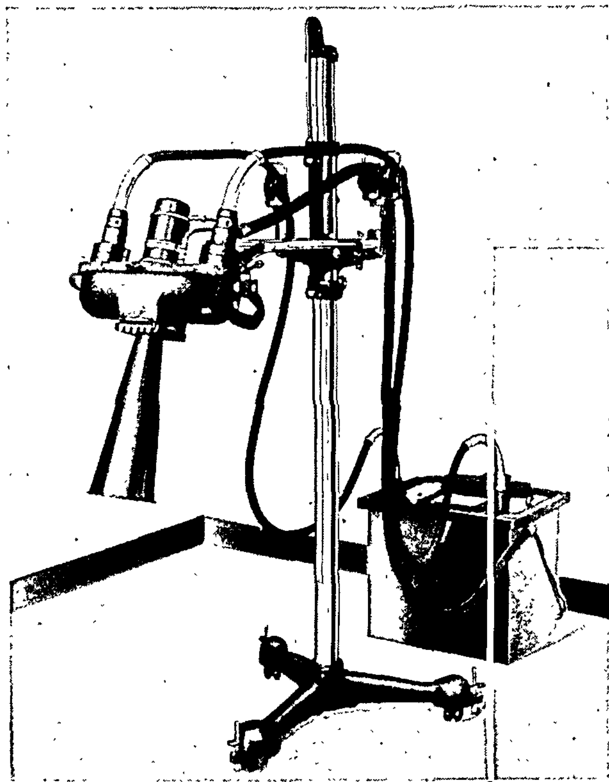

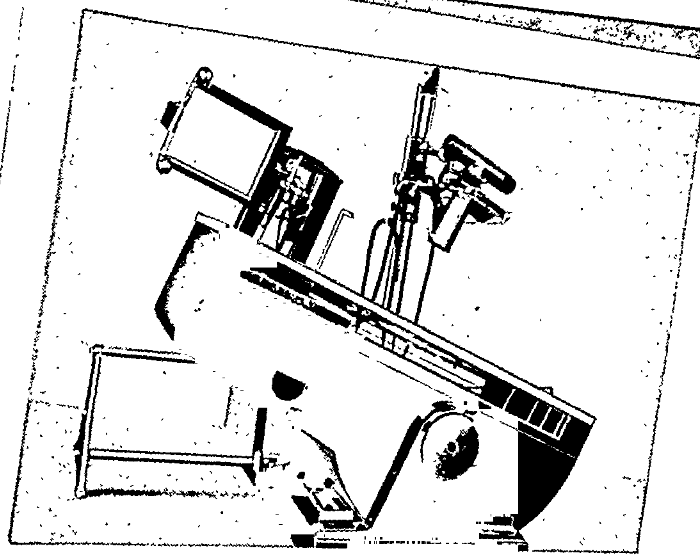

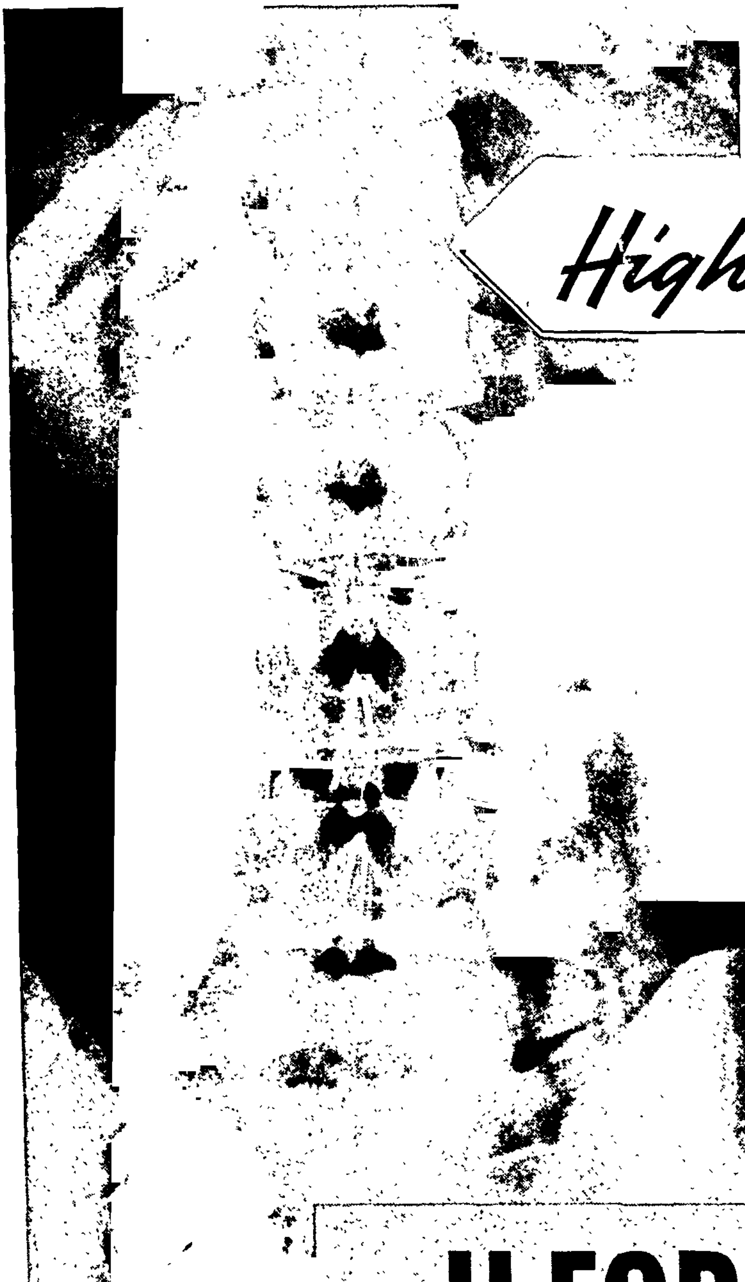

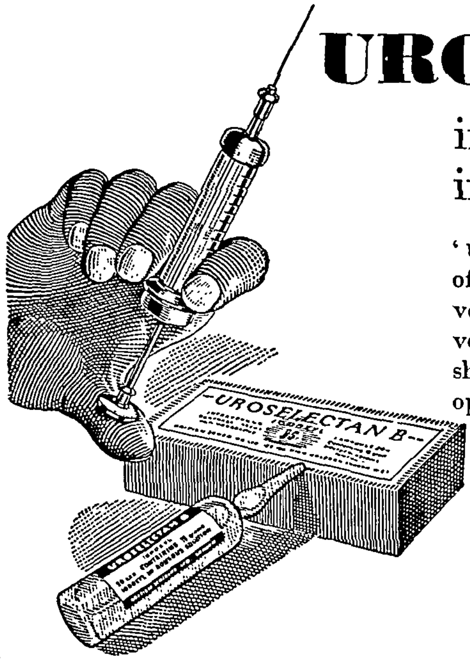

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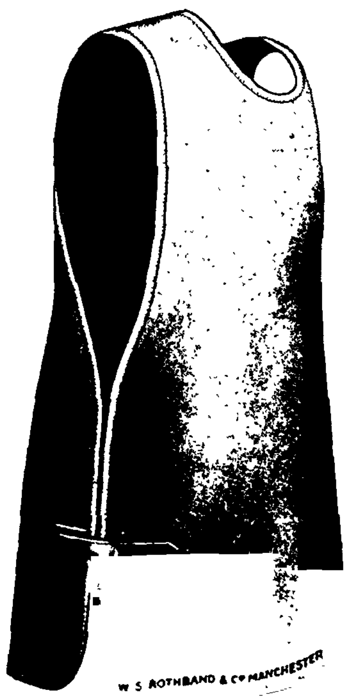

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PROVISIONAL CALCULATION OF THE TOLERANCE FLUX OF FAST NEUTRONS

By J. S. MITCHELL, M.A., M.B., Ph.D., D.M.R.

Professor of Radiotherapeutics, University of Cambridge

UNTIL experimental evidence on the biological effects of fast neutrons at low dose-rates becomes available, it is necessary to calculate the tolerance flux of fast neutrons for energies up to 20 Mev., with especial interest in the region 2–5 Mev.

The problem is to calculate the flux N per cm.^{2} per sec. of fast neutrons of energy E Mev., in an incident beam, required to deliver in eight hours a dose equivalent in biological effects to a given "tolerance dose" specified in röntgens of the usual filtered γ radiation from radium of approximate mean energy 0·8 Mev. At the present stage, it is only possible to evaluate the dose received in a volume element near the surface of the body.

General theory

The relevant theory of the slowing down of fast neutrons by elastic collisions with atomic nuclei has been published by Placzek (1946). The simpler results of this theory have been used in Table I to calculate the average energy loss by the neutrons per collision with the nuclei of the tissue constitutents. A fast neutron is found to lose, on the average in one collision, a certain fraction of its initial energy which is independent of the value of the intial energy. The mean logarithmic energy loss in one collision is shown by Placzek (1946 cf. Eq. 27, 27a, and 28) for the case of slowing down of fast neutrons by elastic collisions and without capture in a pure substance of atomic mass M to be:—

$$a=\left(\log\frac{E_o}{E}\right)\begin{matrix}\text{average per}\\ \text{collision}\end{matrix}=1-\frac{(M-1)^2}{2M}\log\frac{M+1}{M-}\quad .1$$

This expression is evaluated in line 5 of Table I for the commoner tissue constituents and in the last column of the line is expanded for heavy nuclei of mass $M>1$. The average factor by which a neutron loses energy per collision is $1-e^{-a}$; this is evaluated in line 6 of Table I.

For a "mixture" such as tissue, assuming that all the mean free paths are constant or vary in the same way with the neutron energy, Placzek's (1946 cf. Eq. 39) theory shows that the mean logarithmic energy loss per collision:—

$$\bar{a}=\frac{\Sigma_k n_k\sigma_k a_k}{\sum\limits_k n_k\sigma_k}\quad \dots\dots\dots\dots 2$$

where the summation is over all the tissue constituents and for the k^{th} constituent, n_k is the number of nuclei per c.c., σ_k the scattering cross section and a_k the mean logarithmic energy loss per collision for the pure constituent. Hence Σ the energy absorption per c.c. of tissue per second, resulting from elastic scattering is given by:—

$$\Sigma=NE\sum_k n_k\sigma_k(1-e^{-a_k})+\tfrac{1}{2}NE\left\{\sum_k n_k\sigma_k a^2{}_k-\frac{(\Sigma_k n_k\sigma_k a_k)^2}{(\Sigma_k n_k\sigma_k)}\right\}-\quad \dots\dots\dots 3$$

For tissue for neutrons of energy 0·5–10 Mev., of the order of 85–95 per cent. of the total energy

absorption is due to the recoil protons, and only the first term of Equation 3 is important. For the present conditions the second term is an insignificant correction, *e.g.*, for absorption of 3 Mev. neutrons in water, the second term is approximately 0·1 per cent. of the first term.

TABLE I

Data for the Provisional Calculation of the Tolerance Flux of Fast Neutrons

Element	H	C	N	O	P	S	Heavy Nuclei
Atomic Mass M	1	12	14	16	31	32	$M>1$
Percentage by weight in tissue (1)	11	20·2	2·5	~65	1·14	0·14	
Number of atoms per c.c. of unit density tissue (n)	$6{\cdot}6\times 10^{22}$	$1{\cdot}02\times 10^{22}$	$1{\cdot}08\times 10^{21}$	$\sim 2{\cdot}4^{4}\times 10^{22}$	$2{\cdot}2\times 10^{20}$	$2{\cdot}6\times 10^{19}$	
Mean logarithmic energy (2) loss by neutron in one collision $a=\left(\log \frac{Eo}{E}\right)$av.	1	0·1578	0·1363	0·1200	0·0632	0·0612	$\frac{2}{M}-\frac{4}{3M^2}+\frac{2}{3M^3}-\frac{4}{45M^4}+$
Average energy loss by(2) neutron per collision $=1-e^{-a}$	0·6321	0·1462	0·1276	0·1131	0·0613	0·0594	$\frac{2}{M}-\frac{10}{3M^2}+\frac{14}{3M^3}-\frac{254}{45M^4}+$
Cross section for neutrons of energy E Mev. $\sigma\times 10^{24}$ cm.^{2} — E Mev.	(3) σ scattering	σ scattering	σ total	σ scattering	σ total	σ total	
0·5	6·32 ± 0·15	3·26 ± ·10					
1·0	4·16 ± 0·15	2·38 ± 0·09					
2·0	2·96 ± 0·07	1·63 ± 0·04	1·4	1·0			
(4) 2·88	2·36 ± 0·12	1·97 ± 0·05	1·38 ± 0·06	1·25 ± 0·05		3·12 ± 0·15	
3·0	2·33 ± 0·13	1·59 ± 0·08	1·3	1·0			
4·0	1·85 ± 0·09	1·85 ± 0·10	1·6	2·9			
5·0	1·63 ± 0·05	(5) ~1·2 (3) 1·18 ± 0·03	(5) ~1·9	(5) ~1·4		(5) ~4·1	
10	0·85						
15	0·61	1·31(6) 1·23(7)					
20	0·50	1·27(7)					
25	0·39						

REFERENCES.
(1) Bodansky, 1938.
(2) Cf. Placzek, 1946.
(3) Bailey *et al.*, 1946; Frisch, 1946; Good and Goldhaber, 1940; Zinn, Seely, and Cohen, 1939; Salant and Ramsay, 1940; Sleater, 1946, and Scherr, 1942.
See also Bethe and Bacher, 1936, Eq. 62.
(4) Zinn, Seely, and Cohen, 1939.
(5) Aebersold and Anslow, 1946.
(6) Salant and Ramsay, 1940.
(7) Sleator, 1946.

Application of the first term only is not exact, though a sufficiently good first approximation, on account of inelastic scattering by carbon and oxygen and disintegration of nitrogen, and probably also phosphorus and sulphur. The scattering cross sections are known with considerable accuracy over a wide range of energies for hydrogen and carbon and are given in Table I. It is to be noted that resonance peaks occur in the scattering cross section of carbon near 3·6 and 4·3 Mev., and of oxygen near 1 and 4·5 Mev. The contribution to the dose from $N(n, p)C$ and $N(n, \alpha)B$ disintegration reactions is very small, probably less than ½ per cent. (cf. Gray and Read, 1939; Barschall and Battat, 1946). The contribution from disintegration processes in other elements appears to be negligible.

In addition to the data summarised in Table I it is to be noted that 1 röntgen of γ radiation corresponds to the dissipation of 93·1 ergs per gm. of water (cf. Lea, 1946, p.22; Gray, Mottram, Read, and Spear, 1940); also 1 Mev. $= 1{\cdot}602 \times 10^{-6}$ ergs.

Relative biological efficiency

It is now necessary to introduce $\eta \frac{N_E}{\gamma}$ the relative biological efficiency per unit energy absorption for neutrons of energy E in terms of the efficiency of radium γ radiation as unity. No direct measurements of the value of $\eta \frac{N_E}{\gamma}$ for low dose-rates are available. It is known that the value of $\eta \frac{N_E}{\gamma}$ depends upon the specific ionization and hence upon E (see Gray and Read, 1943; Gray, 1946) so that it is not justifiable to assume a constant value, of perhaps 5. Further, for given E, the value of $\eta \frac{N_E}{\gamma}$ varies greatly for different biological processes and different cells. Provisionally it seems best to assume that the biological processes such as lethal effects and cell depletion, upon whose avoidance the tolerance dose-rate is determined, depend upon chromosome interchanges. Thus $\eta \frac{N_E}{\gamma}$ may increase at low dose-rates, perhaps to values of the order of 20 (Mitchell—unpublished experiments). The provisional values of $\eta \frac{N_E}{\gamma}$ given in Table II are selected rather arbitrarily and are based on the results summarised by Gray, Mottram, Read, and Spear (1940), especially Table VII, Gray, and Read (1942 (*a* and *b*), and 1943), Thoday (1942), and Gray (1946).

TABLE II

E Energy of neutron in Mev.	$\sigma H \times 10^{24}$ cm.^{2}	Provisional value of $\eta \frac{N}{\gamma} E$	Approximate percentage recoil energy absorption due to H^1	Approximate flux of fast neutrons per cm.^{2}/sec. to deliver 0·1 r in 8 hours.*
0·5	6·3	9	96	~165
1·0	4·2	9	92	~120
2·0	2·96	9	93	~85
2·7	2·4	8·7	93	~80
3·0	2·33	8·5	95	~75
4·0	1·85	7·5	87·5	~75
5·0	1·63	6	91	~90
10	0·85	5	~85·6	~95
20	0·50	4	~78	~95

* To the nearest five.

Dose in röntgens

The dose in röntgens can now be calculated in terms of the neutron flux by means of the first term of Equation 3.

The contribution from recoil protons to the surface dose is equivalent in biological effects to

$$D_H = \eta \frac{N_E}{\gamma} NE\sigma_H \frac{\times 0{\cdot}632 \times 6{\cdot}6 \times 10^{22} \times 1{\cdot}60 \times 10^{-6} \times 2{\cdot}88 \times 10^4}{93{\cdot}1}$$

$$= 2{\cdot}06 \times 10^{19} \eta \frac{N_E}{\gamma} NE\sigma_H \, r_y \text{ in 8 hours. . . . } 7$$

To obtain the total surface dose, it appears justifiable to correct for the fraction f of the total recoil energy absorption due to H^1 neglecting disintegration processes.

Hence to deliver a surface dose equivalent to 0·1 r of γ radiation in 8 hours required a flux:—

$$N = 4{\cdot}84 \times 10^{-21} \times \frac{f}{\eta \frac{N_E}{\gamma} E\sigma_H} \text{ neutrons per cm.}^2 \text{ per sec. . . } 5$$

The approximate values of this flux are evaluated in Table II for neutrons of energy 0·5–20 Mev. It is interesting to note the approximately constant value of the flux corresponding to a given dose for neutrons of energy 2–20 Mev. The increase in value of the flux for energies below 2 Mev. appears to be significant.

Tolerance Flux

Accordingly the flux of fast neutrons corresponding in biological effects to a dose of 0·1 r of the usual filtered γ radiation from radium of approximate mean energy 0·8 Mev. delivered in 8 hours has the approximate constant value of 85 ($\pm$10) neutrons per cm.^{2} per sec. for neutrons of energy 2–20 Mev. The flux increases to about twice this value for neutrons of energy 0·5 Mev.

The application of this result to the establishment of the tolerance flux of fast neutrons requires great caution. It is by no means impossible that the correct values of the relative biological efficiency $\eta \frac{N_E}{\gamma}$ for tolerance conditions are greater than the values assumed in these calculations by a factor of two. Moreover, while the tolerance dose-rate for total body exposure to the γ radiation from radium recommended by the National Bureau of Standards, Washington (1938), is 0·1 r per day, it has been suggested that it may be desirable to reduce the tolerance dose-rate to 0·05 r per 8-hour day. Hence it is recommended that the provisional tolerance flux of fast neutrons of energy 2–20 Mev. should not exceed 20 neutrons per cm.^{2} per sec. during a period of 8 hours in any one day. This value of the tolerance flux can be doubled for neutrons of energy 0·5 Mev.

It is evident that experimental measurements of the biological effects of fast neutrons at low dose-rates are urgently required.

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SUMMARY

Calculations suggest that the flux of fast neutrons corresponding in biological effects to a dose of 0·1 r of the usual filtered γ radiation from radium of approximate mean energy 0·8 Mev. delivered in 8 hours has the approximate constant value of 85 neutrons per cm.^{2} per sec. for neutrons of energy 2–20 Mev.

On account of the uncertainties involved, it is recommended that the provisional tolerance flux of fast neutrons of energy 2–20 Mev. should not exceed 20 neutrons per cm.^{2} per sec. during a period of 8 hours in any one day. This value of the tolerance flux can be doubled for neutrons of energy 0·5 Mev.

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ACCURACY IN RADON WORK

By F. Ellis, W. A. Jennings, and S. Russ

THE technique of radon is an elaborate one and demands a high degree of skill from those engaged in it. The volume of radon in equilibrium with one gram of radium element (1 curie) is almost exactly 0·6 c.mm. and as many of the needs of the radiotherapist are in terms of millicuries it is obvious that we are dealing with much smaller volumes than are met with in most gaseous processes.

Under ordinary working conditions if a particular requirement of X millicuries is in question, then it can be said that X millicuries within a very few per cent. will be supplied. If, however, this quantity X has to be divided among N items, the question arises as to how the accuracy suffers in the subdivision, as it undoubtedly does.

The small quantities mostly involved are called "seeds"; their dimensions vary in length from 5–17 mm., the average bore of the glass capillaries is 0·45 mm. diameter external and 0·2 mm. internal. The method of making the seeds is first to draw out a length of capillary tubing from 20–40 cm. long; purified radon under less than atmospheric pressure is then passed into the capillary tube which has previously been exhausted to a pressure of about ·001mm. Hg as measured on a Pirani gauge. The capillary is then sealed off either by means of a very small flame or by electrical heating; the subdivision of the whole length is then carried out by successive divisions by half, for only in this way may a drift of radon by convection be avoided. It will be realised that to hold a capillary one cm. in length in a minute pointed flame and divide it into two equal-content parts is a performance that can only rarely come out dead right. We require to know what sort of accuracy does in practice result when these operations are repeated on a considerable scale.

The examples given in what follows have been unselected in any usual sense of the term, for they have been selected at random and represent what is usually attained under the ordinary working conditions at the Radon Centre of the Medical Research Council at Barton-in-the-Clay. It may, however, be said that if any effort had been made to select the best that could be done, the result would have been just the same; for the fact is that the manipulative technique has been carried to the stage when we can see no way of improving it. What, however, can be quite usefully discussed is, how the variations in content of radon seeds can be minimised in therapeutic work and to what extent it is necessary for the radiotherapist to allow for these variations.

The nature of the so-called errors

It is well to bear in mind that what we are dealing with is a set of values or quantities which show deviations on either side of the mean value and that this mean value is not necessarily the correct value, *i.e.*, the value in the mind of the person going to use the radon.

It will therefore be seen that neither is the use of such a term as percentage error in this connection correct nor if it were correct would it be informative. What the user wants to know about a group of seeds is what is the normal deviation. Given this, he can realise at a glance whether it is worth while for him either to minimise its significance or to allow for the variability in question by some new disposition of an already planned technique.

It may be said that the deviations are for the most part due to non-uniform distribution of the radon within the capillary tubing; on repeated sub-division this shows itself by a range of content among the seeds which is often considerable.

Impracticability of elimination

The question arises as to whether the seeds above or below the mean value could not be eliminated. There are two reasons why this is impracticable. (*a*) the deviation is not determined in practice owing to the large amount of exposure to β and γ radiation that it would involve to those engaged in the work, so that we do not know which seeds to reject and (*b*) even though individual measurements were made, the number of rejects calling for extra seeds would become impractically high if the same degree of accuracy were expected among the seeds as we get from their totals; as will be seen from the data below, the total radon in a batch of seeds (10 to 20–70 in number) does as a rule come out extremely near to the total that is requisitioned. To approximate to this accuracy among the seeds is not impossible but it is at present impracticable.

Experimental readings and results

The following tests were carried out under perfectly normal working conditions, no special

precautions being taken. Three sample sets of seeds were analysed, the 3 sets having different glass lengths, *viz.*, 7·5 mm., 5·5 mm., and 5·0 mm. As a convenient means of expressing the magnitude of the variations in activities involved, the *standard deviation* σ was calculated in each case,

$$\text{where } \sigma = \sqrt{\frac{\Sigma(x-x)^2}{n}} \ *$$

x being any observation, and x the arithmetic mean of all the n observations.

Alternatively, we may refer to the *probable error* ν; this is the error which is as likely to be exceeded as not exceeded, and is given by the expression

$$\nu = \frac{0{\cdot}843\, \Sigma\, |x-\bar{x}|}{n}$$

Case I

A group of 12 seeds, each 7·5 mm. in glass length and to contain 3·0 mc. each.

Individual values in mc.

3·33	3·16	2·82
3·22	3·16	2·80
3·20	3·13	2·75
3·18	3·01	2·59

The mean value is 3·03 mc., so that the complete set itself is 1 per cent. out. The standard deviation $\sigma = 0{\cdot}221$ mc., which is 7·35 per cent. of the mean activity, whereas the probable error ν is 5·3 per cent.

A further consideration can be suitably introduced at this point, namely, the *proportion of the total number of seeds whose activities lie within a given percentage of one another*—not necessarily about the mean value of all the seeds, so long as the mean activity of those seeds concerned falls within the specified percentage limits (usually 10 per cent.) of the value ordered by the client. The proportion of the total of a sample population falling within certain limits can be derived from the figure calculated for the standard deviation σ, but such a derivation rests on the assumption that the distribution of readings obeys a Gaussian normal error law, and for reasons to be discussed later (see p. 186) will yield a lower proportion of "successful" seeds than is actually the case—as derived by *direct analysis*.

Individual readings in mc.

3·33
3·22
3·20
3·18
3·16
3·16
3·13
3·01
2·82
2·80
2·75
2·59

(readings 3·33 to 3·01): $\frac{3{\cdot}33-3{\cdot}01}{3{\cdot}17} \times 100 = 10{\cdot}01$ per cent.

(readings 3·33 to 3·13): $\frac{3{\cdot}33-3{\cdot}13}{3{\cdot}20} \times 100 = 6{\cdot}25$ per cent.

Thus, 58·3 per cent. of the total number are within 6·25 per cent. of one another, and 66·7 per cent. are within 10·0 per cent. of one another. But these practical results are obtained by choosing mean values of 3·20 mc. and 3·17 mc. respectively as shown, and thus leaving out of consideration those readings whose values are more scattered. Taking all readings into account, the normal error law leads to a figure of 50·7 per cent. for a 10 per cent. limit in variation.

For this set of seeds, then, the activities of two-thirds are within 10 per cent. of one another, from which result it is seen that at least half as many again would be required as spares if a 10 per cent. limit were set to the permitted variation for this length of seed.

Case II

A group of 16 seeds, each 5·5 mm. in glass length and to contain 1·5 mc. each.

Individual values in mc.

1·85	1·60	1·45	1·36
1·80	1·51	1·39	1·29
1·78	1·47	1·39	1·26
1·75	1·45	1·37	1·17

The mean value is 1·49 mc., so that the complete set is only 0·46 per cent. out. The standard deviation $\sigma = 0{\cdot}20$ mc. which is 13·3 per cent. of the mean activity, and the probable error ν is 9·0 per cent. Further, direct analysis shows that half the total

* We are here concerned with the deviations about a mean value which, though arbitrary, corresponds to the "true value", for there is no question of approximating to some unknown "real" mean for any given set of seeds. Accordingly, it is correct to employ (n) and not (n—1) as divisor in the expression for σ, for there is no need to effect a reduction in the number of effective "degrees of freedom"—such a correction arising only in connection with observational *errors* in the measurement of an observed quantity whose true value differs from the arithmetic mean of the readings.

number of seeds have activities lying within 10 per cent. of one another, so that it would be necessary to make at least double the required number, if such a limit were set to the permitted variation for this length of seed.

Case III

A group of 10 seeds, each 5·0 mm. in glass length and to contain 3·0 mc. each.

Individual values in mc.

3·80	3·03	2·38
3·22	2·88	2·30
3·08	2·82	2·20
	2·72	

The mean value is 2·84 mc., so that the complete set is 5·3 per cent. out. The standard deviation σ is 0·457 mc., which is 16·0 per cent. of the mean activity, and the probable error ν is 10·7 per cent. For this set of seeds, direct analysis shows that two-fifths of the total number of seeds have activities which lie within 10 per cent. of one another, so that at least 2½ times the number of seeds on order would have to be made in order to include the required number complying with such limiting conditions.

Analysis of the above experimental results:

(*a*) *Relation of glass length to standard deviation*

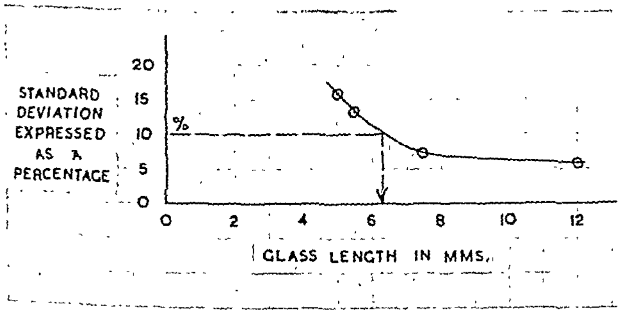

Fig. 1
Relation of glass length to standard deviation.

Though the amount of experimental data scarcely justifies the drawing of the accompanying graph (Fig. 1), it serves to illustrate the relative importance of the three sources of error to be dealt with and gives some indication of the order of error involved in terms of the standard deviation. In particular, the correlation between the standard deviation and the length of the seed is seen to be as expected (see p. 181), and the approximate length at which this factor becomes important is clear. There will naturally be some variation in the value of the standard deviation σ for different sets of otherwise similar seeds owing to the small numbers involved, but the actual difference between σ for such typical sets and that calculated for a large number of seeds is probably small (see p. 184). Numerically then, it is seen that owing to the operation of the three sources of error—namely, variations in the length, in the bore, and in the gas pressure within the glass seeds—a standard deviation σ of 5–8 percent. is to be expected for any length of seed or needle greater than 7 mm., but that for seeds prepared by the ordinary technique containing glass lengths under 6·5 mm., σ will probably exceed 10 per cent.

(*b*) *Relation of glass length to the percentage number of seeds within a given percentage activity of one another*

Analysis of the experimental results given above yields the data given in Table I.

If the fraction of the total number of seeds which have activities between set limits is p, then the minimum number of seeds which will have to be made is equal to $(1/p)$ times the number ordered, on the assumption that the mean value of the group of seeds within the set limits is also within 10 per cent. (say) of the value ordered, an assumption which does not invariably hold good. Applying this principle to the above results expressed in graphical form (Fig. 2), it is seen that the minimum number of seeds which would have to be made for an order of 40 seeds of glass length 7·5 mm. for them to be within 10 per cent. of one another would be 60, and within 5 per cent. of one another, 80. If, however, the seeds had a glass length of 5·0 mm., the corresponding figures would be 100 and 200. In actual practice, greater numbers would have to be made as spares.

Table I

Length of seed mm.	Percentage number of seeds within set limits of activity.	
	Within 10% of one another	Within 5% of one another
5·0	40%	20%
5·5	50%	32%
7·5	67%	50%

As explained, these larger variations among the activities of short seeds are due primarily to variations in glass length, thus becoming less important for seeds and needles over 8 mm. in length; but for seeds of 7 mm. screen length, the probable error ν is increased from 6·8 to 10·7 per cent. if they are threaded on account of the millimetre length occupied by the knot. Accordingly, bearing in mind the figures for the probable error to be expected for a complete normal set of seeds (prepared by the usual technique) it is for the client to specify whether the reduction of such an error among the seeds actually supplied is essential; but if certain narrow limits to the percentage relative activities of the component seeds forming a group are set, it should be understood that it will involve the full preparation of a larger number of seeds than are required, the individual measurement of every one, and the rejection of those whose activities lie outside the specified limits. For small numbers of seeds, such a procedure is practicable, whereas in the case of a large number of short seeds (such as may be required in the treatment of a tongue or bladder), the random distribution of the seeds themselves may effectively compensate for the variation in their individual activities.* Accordingly, the process of rejection of a somewhat high percentage of the seeds frequently becomes unnecessary, thus saving radon and undue exposure to the radiations on the part of the technician. Fewer spares would be required in the case of seeds or needles whose glass length exceeds 8 mm., but the probable error ν is only about 5 per cent. without rejections, which is generally satisfactory.

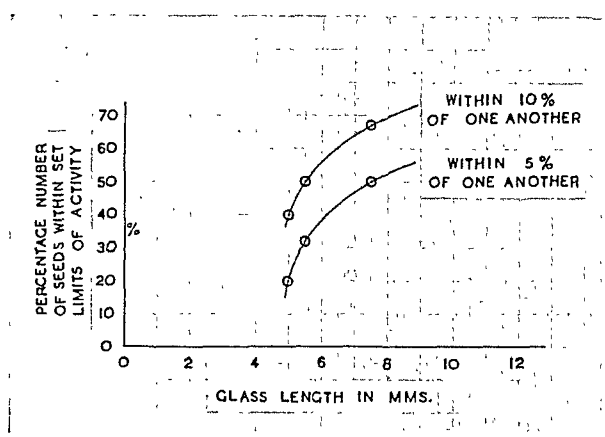

FIG. 2

Relation of glass length to the proportion of "successful" seeds.

The distribution of errors among the activities of a given set of seeds

In order to investigate the actual distribution among a set of readings for a typical sample set of seeds, a test was carried out on a group of 36 seeds—this number being selected as a minimum suitable for the purpose of drawing a "frequency-range" graph.

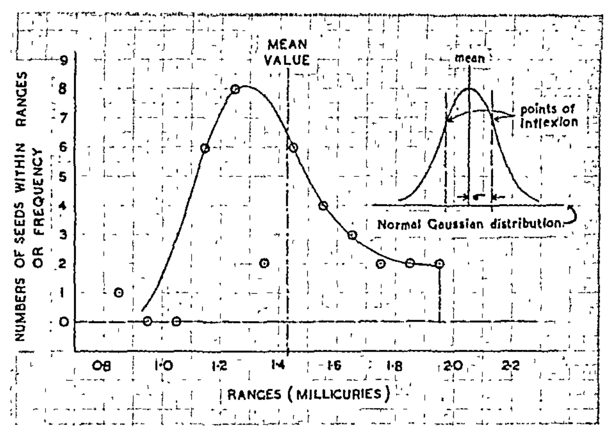

FIG. 3

Frequency-range graph for a particular set of seeds.

Readings: glass-length 5·0 mm.

Individual values in mc.

1·96	1·69	1·53	1·41	1·24	1·18
1·93	1·68	1·48	1·37	1·24	1·18
1·86	1·65	1·44	1·36	1·22	1·15
1·80	1·58	1·43	1·29	1·22	1·15
1·76	1·58	1·43	1·29	1·22	1·14
1·75	1·57	1·43	1·29	1·19	0·86

The mean value of these 36 seed activities is 1·43 mc., the standard deviation σ is 0·256 mc.—or 17·9 per cent.—and the probable error ν is 12·3 per cent. It is of interest to compare these figures with those obtained for Case III on page 183, the latter being for a group of 10 similar seeds of the same short glass length (5·0 mm.). The corresponding figures were $\sigma = 16{\cdot}0$ per cent. and $\nu = 10{\cdot}7$ per cent., which may be regarded as satisfactorily consistent in view of the small numbers involved.

* Two factors enter here: (*i*) the inevitable small variation in spacing and (*ii*) a weak seed may well have a strong seed as neighbour.

From the above set of individual readings, the following Table II can be derived:

TABLE II

Range in mc.	Frequency	Range in mc.	Frequency
0·80–0·90	1	1·40–1·50	6
0·90–1·00	0	1·50–1·60	4
1·00–1·10	0	1·60–1·70	3
1·10–1·20	6	1·70–1·80	2
1·20–1·30	8	1·80–1·90	2
1·30–1·40	2	1·90–2·00	2

When plotted, the "frequency-range" graph given in Fig. 3 is obtained.

In the same figure, the "normal (Gaussian) frequency distribution" graph is also given, for it can be shown to represent the distribution of such random errors, provided the number of readings is sufficiently large to smooth out irregularities. But a further point must not be overlooked—namely, that we are here dealing with three independent sources of error (*viz.*, variation in length of seed, bore, and gas pressure) and in view of the comparatively small number of seeds involved, the possible interrelations of these factors may well lead to errors which are more marked than if a single factor caused the variations. Such an effect can in fact be seen in the results plotted in Fig. 3, for the distribution clearly deviates from the normal Gaussian form in that it is markedly "lop-sided"—indicating that the sources of error happened to combine in an uneven manner.

If, however, it is assumed that the distribution of readings complies nevertheless sufficiently closely to a Gaussian normal error law of the form:

$$\phi(x)\,dx = \frac{1}{\sigma\sqrt{2\pi}}\,exp.\left(\frac{-x^2}{2\sigma^2}\right)$$

certain measurable results can be derived from which the validity of the assumption can be tested. Let us consider the probability of an error lying between α and $-\alpha$ (symmetrical case). This is given by the expression:

$$P(\alpha,-\alpha)=\int_{-\alpha}^{\alpha}\frac{1}{\sigma\sqrt{2\pi}}\,exp.\left(\frac{-x^2}{2\sigma^2}\right).dx$$

$$=\frac{1}{\sigma}\sqrt{\frac{2}{\pi}}\int_{o}^{\alpha} e^{-x^2/2\sigma^2}.dx$$

Putting $Z=\dfrac{x}{\sigma\sqrt{2}}$; $dZ=\dfrac{dx}{\sigma\sqrt{2}}$, we have

$$P(\alpha,-\alpha)=\frac{\sqrt{2}}{\sigma\sqrt{\pi}}\int_{o}^{\frac{\alpha}{\sigma\sqrt{2}}} e^{-Z^2}\,\sigma\sqrt{2}.dZ$$

$$\frac{2}{\sqrt{\pi}}\int_{o}^{\frac{\alpha}{\sigma\sqrt{2}}} e^{-Z^2}.dZ$$

But, introducing the error function "*erf x*"

where $erf\ x=\dfrac{2}{\sqrt{\pi}}\displaystyle\int_{o}^{x} e^{-Z^2}.dZ$

we have $P(\alpha,-\alpha)=erf\left(\dfrac{\alpha}{\sigma\sqrt{2}}\right)$

from which result we can calculate (making use of error function tables) the probability of an error lying between set limits $\pm\alpha$, and hence the percentage number falling within a chosen percentage activity of one another. Such results can then be compared with the figures derived by direct analysis for the three cases given on pages 182 and 183.

If the seeds activities are to be within 10 per cent. of one another, α may be taken as equal to $\pm$ 5 per cent. of the mean value.

CASE I: Standard deviation $\sigma=0{\cdot}221$ mc.
Mean value $=3{\cdot}03$ mc.
$\alpha=0{\cdot}1515$ mc.
Hence, the required probability P is given by $P=erf\left(\dfrac{\alpha}{\sigma\sqrt{2}}\right)$

$$=erf\,(0{\cdot}4845)$$
$$=0{\cdot}507$$

Therefore, the activities of 50·7 per cent.* of the total numbei of seeds are within 10 per cent. of one another. But by direct analysis of the individual

* 50·0 per cent. of the total number of seeds are successful for a range of $\alpha=\pm0{\cdot}678\sigma$.

activities, it was found (p. 182) that 66·7 per cent. of the total number had activities within 10·0 per cent. of one another and 58·3 per cent. bad activities within 10·0 per cent. of one another (a step of 8·4 per cent. in the number, there being only 12 seeds in all).

A similar discrepancy is found in the figure derived for the other two sample sets of seeds:—

	Percentage number with activities within 10% of one another
CASE II:—	
(*a*) By calculations based on the value of σ	29·3%
(*b*) By direct analysis	50·0%
CASE III:—	
(*a*) By calculations based on the value of σ	24·4%
(*b*) By direct analysis	40·0%

The reason for the discrepancy can be seen from the graph given in Fig. 3, for the number of seeds within chosen limits of activity is proportional to the area under the curve between the appropriate ordinates, and in practice one is entitled to place these limits about the maximum of this frequency-range graph, so long as the mean value of the total chosen remains within the specified limits. Accordingly, one would expect to obtain a greater percentage of "successful" seeds by this method of direct analysis than if the limits are defined about the mean of the derived normal error curve, the derivation of which includes a consideration of all the seeds, however wide of the mark. In practice, the "successful" seeds must inevitably be found by direct analysis, but the above results show how calculations involving the assumption of the validity of the normal error law will lead one to expect a lower proportion of successful seeds than is actually the case.

One advantage in using radon in these days of bed shortage is that patients can be treated without the stay in hospital necessitated by the value of radium element. Of course, it is essential that the radon should stay in position and that there should be no hitch in its removal, if it is to be removed. Neither should the procedure be too much for the patient to tolerate as an out-patient, nor should the management of the case suffer any disadvantages from such out-patient treatment. By suitable selection of patients, however, many are found who can be treated as out-patients both by surface applications and implants of radon.

Another advantage is the possibility of variation of technique by using varied instead of fixed sources of γ radiation. It is a disadvantage, however, that radon loses its γ-ray intensity so that for a treatment to last one week 1·75 mc. of radon must be used instead of 1mg. of radium so that the exposure to which the radiotherapist is subjected is increased to 175 per cent. at insertion although diminished to about 45 per cent. at removal. The diminution introduces an unknown and therefore undesirable variation in the time intensity relationship but in practice this does not seem to be of great importance in treatment times of about one week.

The practice of leaving seeds in perpetuity, however, and reckoning 132·4 mgh. per millicurie destroyed seems unjustifiable from a biological point of view. In twelve days a source of 1 mc. will be reduced to 0·10 mc. and the γ-ray dose at 0·5 cm. will be reduced to about 3 r per hour.

It seems likely that such low dosage-rates might be quite ineffective in their influence on malignant tumours. In any case such effects are unknown and should be dispensed with if possible. Because of this it seems desirable that radon sources should, when implanted, be removed in the same way as radium sources and that seeds should be ordered as threaded, for removal in such cases.

This paper is not concerned with the whole technique of radon treatment but with the possibility of increasing the accuracy of such treatment.

The inaccuracies already described as inseparable from the most perfect technique can only be compensated for in two ways. One is by the preparation of many more seeds than are required and discarding more than half. The other is to use all the seeds as prepared and thus halve the exposure to which the radon technician is subjected. From the point of view of the radiotherapist it is important to arrange the radon in such a way as to obtain a uniform dose of radiation over the area it is desired to treat by a Paterson-Parker (1934) type of distribution.

This is desirable because unless a uniform dose is given some parts must be overdosed and others underdosed and whether the treatment is successful or not in eradicating the tumour, it is not possible to estimate what is the optimum dose unless a uniform dose is given. The seeds as they are despatched from the radon centre may show even greater variation in content than in the examples given. Usually a total radon measurement has been made and so the radiotherapist, even if he realises the possibility of variation in content, cannot know which are the

seeds with a relatively high content and which are those with a low content. There is only one remedy for this—measurement of the content of individual seeds. For this purpose some instrument for rapid *measurement of the seeds is desirable (Kemp 1945).*

This measurement would probably be best carried out at the radon centre, but under present circumstances such measurements are not practicable on the grounds of space difficulties and the added exposure to radiation of a staff which is already working under threshold conditions of safety. Therefore the seeds should be requisitioned only by departments suitably equipped to make the necessary measurements since the alternative is for a number of patients with curable lesions to be treated under conditions of false security with results possibly discreditable both to the method and the practitioner.

That this is not an idle statement is illustrated by the fact that one of the writers (F.E.) first had his attention drawn to the necessity for making these measurements by the failure of theoretically "good" arrangements of radon seeds to give the expected uniform *reaction. For the clinical reaction to indicate* possible physical inaccuracies is a feature of modern γ-ray therapy only possible since the introduction of methods for ensuring uniform absorption of radiation over the region treated.

The radon sources having been measured, it is desirable to have an effective way of labelling them so that they do not become mixed. At the London Hospital this is done by putting them into numbered holes in a lead block and at the same time making a list of the content of the source corresponding to each number. The blocks are made so that they can be boiled before the seeds are put into them and so that they can be immersed in spirit so that the holes containing the seeds fill immediately and completely with spirit when the block is put in the spirit. Radon needles may be boiled, but glass-platinum seeds may not because wax is used to hold the glass in the platinum sheath.

The radiotherapist now has a batch of seeds, the content of each of which is known. A batch usually shows the kind of variation shown in Case II, page 182, and the problem now is how to implant the seeds so as to compensate for the inequalities of radon content.

Suppose the factors for treatment are as follows:—

To treat a circle by an implant.

Diameter 3·5 cm.

Area 9·5 sq.cm. Circumference 11·0 cm.

For a uniform dose to be absorbed at ½ cm. from the plane of radium; for 1000 r —220 mgh., for 6000 r —1320 mgh.

Arrangement to be used: 2 circles.

Outer circle to consist of 11 seeds of about 75 per cent. of the total.

Inner circle to consist of 5 seeds of about 25 per cent. of the total.

Therefore 16 radon seeds ordered of a total content of 13·6 mc. so as to give 97 mgh./mc. in one week. Each seed 0·85 mc.

16 *radon seeds.* Actual content in mc.

1·02	0·88	0·79	0·75
0·99	0·83	0·76	0·71
0·98	0·81	0·76	0·69
0·96	0·80	0·75	0·64

Total radon content is 13·30 mc.

Average radon content = 0·83 mc.

If the 5 smallest seeds are used for the inner circle we see that they contain 3·54 mc. This is 26·6 per cent. of the total. This is within the limits of attain*able accuracy and is therefore satisfactory.*

The remaining 11 seeds are to be arranged in the outer ring so as to overcome the difficulties due to the inequalities.

The arrangement followed is shown in the diagram:—

A
1·02
B 0·76   0·76 *K*
C 0·99   0·98 *J*
D 0·79   0·80 *I*
E 0·96   0·88 *H*
F 0·81   0·83 *G*

Total = 9·76. Average = 0·887.

A, B, C—Largest group of three adjacent seeds 2·77 mc.

G, H, I—Smallest group of three adjacent seeds—2·51 mc.

The maximum variation if compared in groups of three adjacent seeds is thus: 2·77 − 2·51 = 0·26 mc.

As a percentage of the average this is:

$$\frac{0{\cdot}26}{3\times0{\cdot}887}\times 100$$
$$=\frac{0{\cdot}26\times100}{2{\cdot}66}$$
$$\simeq 10 \text{ per cent.}$$

This arrangement is quite simply arrived at as follows:—

If the seeds for the outer ring are numbered in order of descending magnitude 1-11, the same arrangement appears as follows:—

```
        1
    11     10
   2          3
   9          8
     4      5
       7  6
```

The essential point in this arrangement is to put the two smallest (11 and 10) on either side of the largest seed (1), and then the two next largest (2 and 3) on either side of them; the two next smallest (8 and 9) are then used on either side of these—and so on.

In this way the optimum arrangement of the seeds is obtained. In practice the way this is done is for the radiotherapist to decide on the order before starting to insert the seeds and then, knowing the number of the seed in the descending scale, either to call for the one he wants or to write down the order in which they should go round the circle and insert them accordingly.

The same plan is followed with the inner circle.

The seeds for this are:—

12	13	14	15	16
0·75	0·75	0·71	0·69	0·64

The arrangement is as follows:—

```
          a
          12
  b 16          15 e
     13       14
     c         d
```

$abc = 2{\cdot}14$, $bcd = 2{\cdot}10$, $cde = 2{\cdot}15$, $dea = 2{\cdot}15$, $eab = 2{\cdot}08$.

This circle is, of course, half the diameter of the first and is best inserted so that the largest seed in the inner ring is on the same common diameter of the two circles as the largest in the outer ring but on the opposite side of the common centre. In this way the optimum arrangement of the unequal sources can be obtained. The same arguments apply, of course, to surface applications.

As will be seen from the analyses of the variations which have been given, the longer the glass seed up to about 10 mm. the less is the probable error and so the following rules should be followed in ordering:—

1. Order seeds or needles of active length 12 mm. or more if possible.
2. Do not order threaded seeds unless the thread is essential.

For *rectangular arrangements* long tubes or needles are commonly employed and because there may be only four needles in the periphery it may be impossible to use the same type of arrangement to compensate for inaccuracies. The longer needles or tubes, however, are less likely to be inaccurate.* However, there are often clinical considerations which may determine, if one needle contains more radon than a similar needle, which place should be taken by each, when an alternating arrangement is impossible.

The tubes are of 0·5 mm. platinum wall thickness and are not suitable for implanting beyond a length of 4 cm. because of the ease with which they bend. If they bend, of course, the contained glass breaks and the radon escapes. As a result of this there is a danger to all present of inhalation of the radon, the certainty of underdosage, and uneven dosage of the lesion by γ radiation. Necrosis locally due to α radiation from the radon is unlikely because the radon is likely to diffuse rapidly into the blood and be carried elsewhere in great dilution. For lengths greater than 4 cm., needles should be used. For *a volume implant* similar alternation of radon seeds or needles is possible to achieve an optimum arrangement of unequal sources. For *a line source of radon* arranged as seeds, the effect of a uniform radium line source can be obtained with similar alternation, *e.g.*, for a line requiring 6 seeds, the order would be for seeds numbered 1–6 in descending order of magnitude:—

1, 6, 2, 5, 3, 4

but it is often possible, bearing in mind the shape of the isodose curve required, to arrange the radon so as to produce something more nearly akin to what is required than by an ordinary line source of radium. Indeed, it is often desirable to order the radon sources for such an arrangement of varying strengths as calculated by the physicist from data given by the radiotherapist, so that the optimum isodose surfaces around such a line arrangement can be produced by the arrangement of the radon sources.

Differentially loaded tubes

It is possible by using differentially loaded radium tubes to avoid the necessity for crossing their ends as

* Measurement is still needed for them, however. There is always a danger of gross inaccuracy due to the occasional unavoidable human error. The writers have known of cases in which a tube contained no radon at all owing to the glass tube having slipped out of its platinum sheath.

in the usual radium needle rectangular implant. It is also possible to deal with a cylinder so as to get an almost flat isodose surface at the end instead of a markedly re-entrant surface such as occurs unless the end of the cylinder is crossed.

The necessary arrangement of radium in such needles has been discussed by Stewart* (1946).

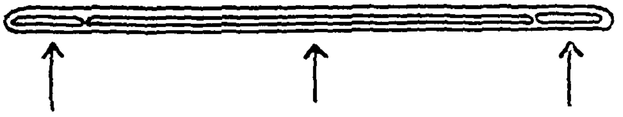

FIG. 4.

Radon lends itself admirably to an experimental technique of this kind. The differentially loaded tube required should be calculated by the physicist. A needle is often not desirable because the chief use of such a tube may be to avoid having an inactive length at its ends.

The kind of arrangement which has been used in treating a case of epithelioma of the tongue has necessitated the ordering of differentially loaded tubes arranged as in Fig. 4.

* Details of the loading of needles and tubes for this purpose have been worked out, first by Frank Teddam and later by F. S. Stewart at Mount Vernon Hospital, following a suggestion by L. H. Gray.

It is intended in future to use seeds already contained in 0·3 mm. platinum, in stainless steel sheath tubes so that the necessary measurements and alteration of the sources can be carried out at the radiotherapy centre.

This paper has been written because it is considered that many using radon do not appreciate all the difficulties associated with its preparation or the dangers of inaccuracy in its clinical use. Incidentally, it is felt also that its possible advantages are insufficiently realised. These advantages may be unreal if the radon is not used in such a way as to ensure reasonable accuracy.

One of the objects of this communication is to bring the facts to the notice of those who use radon and to assure them that unless some new or modified method of handling radon is developed a group of seeds is to be looked upon as a group of individuals having a range of values which may well have to be taken into account in any technical plan of treatment involving their use.

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PATERSON, R., and PARKER, H. M., *Brit. Journ. Rad.*, 1934, 7, 592.
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ERRATA

In Dr. J. F. Brailsford's acknowledgment at the end of his article on "Roentgen's Discovery of X rays", Vol. XIX, No. 227, p. 461, the word "translation" should be in the plural and read "translations".

Dr. Brailsford writes: "Lest the omission should give the wrong impression that Otto Glasser's contribution is merely a translation of his own erudite work published in the German by Julius Springer, the author wishes to apologise for the omission and to emphasise his indebtedness to the work."

The Editors wish to associate themselves with this expression of regret and to correct any false impression that Otto Glasser was not the author of the work referred to.

In the article "Some Experiences with Bone Tumours", Vol. XX, No. 232, p. 137, in the eleventh line from the top of the right-hand column, the word "disease" should read "disuse".

VOL. XX, No. 233

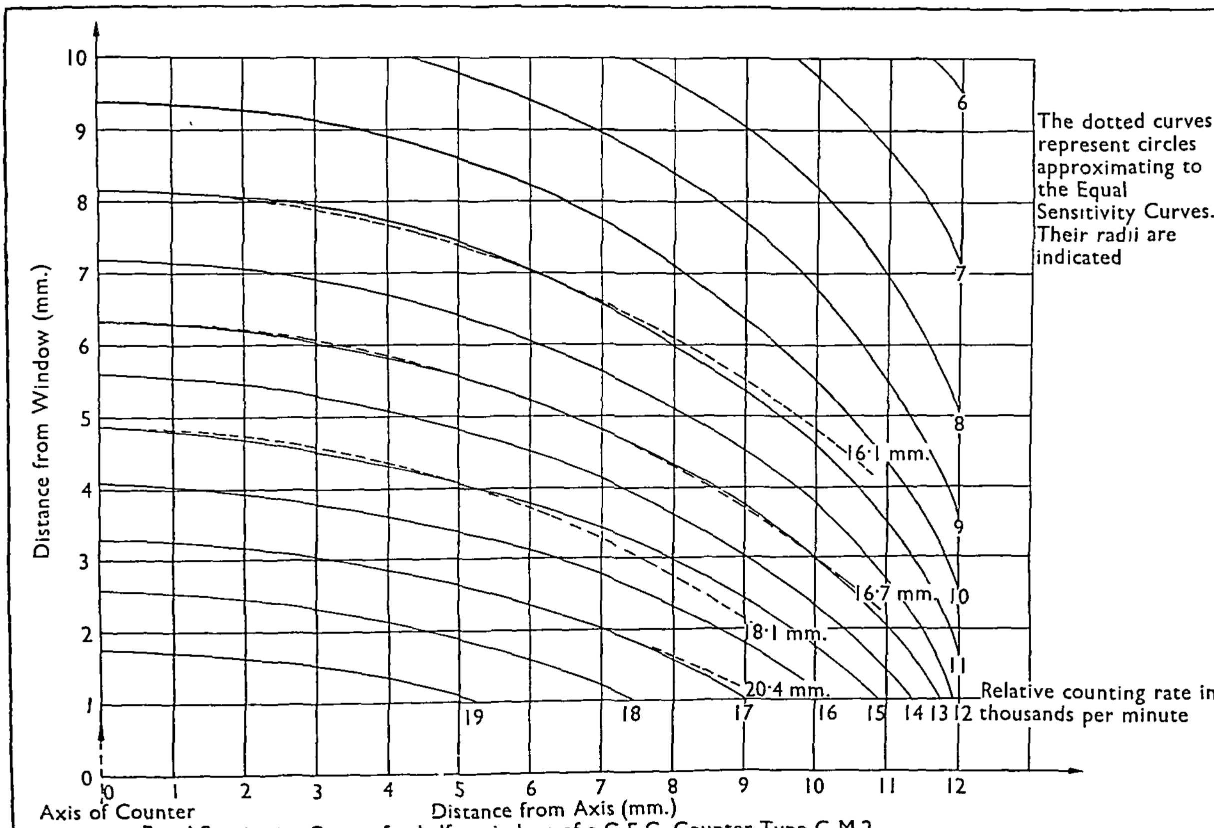
SURFACES OF EQUAL SENSITIVITY NEAR THE WINDOW OF A G.E.C. GEIGER COUNTER TYPE G.M.2

By J. L. PUTMAN and R. H. BOXALL
Atomic Energy Research Establishment, Harwell

WHEN measuring the activity of radio-active films with a β-particle counter, it is required that the counter be equally sensitive to radiation from all points on a film so that the counting rate obtained from a sample shall be substantially independent of its shape and distribution. Such films are normally deposited on glass dishes. It was desired to find the optimum shape of such a dish for radio phosphorus sources, using a G.E.C. end-window counter, type G.M.2.

Assuming the dish to be a surface of revolution about the axis of the counter, it was necessary to measure the sensitivity distribution in one plane only, through this axis. Curves of equal sensitivity in this plane were plotted. To this end, the counting rate from a point source was measured at the intersections of a rectangular lattice in an axial plane of a specimen counter. The source was formed by evaporating a solution of P^{32} on the tip of a tapered brass rod, of diameter $\frac{1}{16}$ in. Correction was made hourly for decay of the source, assuming a half life of 14·30 days.

The source and the counter were mounted on a jig and were adjustable in directions at right angles by means of lead screws. The scales made possible a setting accuracy of $\pm 0{\cdot}1$ mm. The counter was clamped in position with a brass plate pressed against the base flange. The plate was $\frac{1}{32}$ in. thick and therefore thick enough to stop β particles from P^{32}. A circular hole of diameter 1 in., cut in the centre of this brass plate, was carefully aligned with respect to the cathode of the counter. This limited the aperture of the counter to a diameter equal to that of the cathode. By screening the irregular edges



Equal Sensitivity Curves for half a window of a G.E.C. Counter Type G.M.2

of the window from the source in this way, more reproducible sensitivity distributions were obtained from counter to counter. The screening made no measurable difference to measurements within 12 mm. of the axis of the counter.

The counting rate was measured at each point of the measuring lattice. From 10,000 to 20,000 counts were taken in each measurement.

By interpolation along the lattice lines in two directions at right angles, curves were plotted of source positions giving equal counting rates. These curves are shown in the diagram for half the window of a counter. Distances from the window are measured from a plane through its periphery. Rotation of the curves about the axis of the counter generates surfaces of equal sensitivity to a P^{32} source. The counting rates marked on the curves indicate the relative sensitivity of the counter to sources placed on these curves. They refer to an arbitrary source strength, as no standard source was available.

Twelve other counters were used for comparison. Sensitivities were found to be within 9·8 per cent. of a mean value for a source placed on the axis at 5 mm. from the window. The two counters which showed the widest deviation from this mean were used to check the generality of the surfaces of equal sensitivity. Four representative curves of equal sensitivity were checked with each counter after additional scales had been fitted to give positional accuracy of 0·02 mm. Counting rates were constant along the curves tested to within less than ± 2 per cent. up to a distance of 9 mm. from the axis of the counter.

It may be seen that the curves of equal sensitivity approximate closely to circular arcs up to a distance of 7·5 mm. from the axis of the counter. The errors involved in using spherical surfaces for the sample dishes are negligible for most practical purposes if the appropriate radii of curvatures are chosen, and if the dish diameters do not exceed 15 mm.

Summary

Relative sensitivity curves are given for an end window type β- particle counter. The curves are contours of equal sensitivity, to a radio phosphorus point source placed in front of the window, in a plane through the axis of the counter. Surfaces of equal sensitivity may be generated by rotating the curves about the axis of the counter. These surfaces approximate to spherical surfaces near the counter axis. The sensitivity curves were obtained with a counter of average sensitivity. They were checked against two other counters representative of the least and most sensitive counters of this type, and the divergence from equal sensitivity along the curves was less than 2 per cent.

REVIEW

Result of Radium and X-ray Therapy in Malignant Disease (Report on work of Holt Radium Institute).

The Holt Radium Institute has produced in this report a model of clear factual statement which should act as a stimulus to radiotherapists to do the same. The high standard both of conception and execution of the report is what we have learned to expect from Manchester, and Dr. Paterson and his collaborators are to be congratulated on the report as it stands, as well as on the results of treatment, and the skill, intelligence, and organisation which lie behind them.

An essential feature of any scheme for cancer treatment must be the education of the public in the necessity for a suitable organisation for treatment of patients, and for bringing patients under the influence of such an organisation at an early stage in the disease. An account of the organisation behind these results, with figures showing the way in which the numbers grew as its work became appreciated, together with a general survey of the results, will provide ammunition for any crusader for organisation to achieve early effective treatment of patients.

The second part of the report is of interest to the radiotherapist as showing the difference in five-year survivals obtained with different technical methods in the same situation. The figures give a clear and true representation of the facts as far as the author of this review can judge, but while they show that in the groups treated one method may have produced better results than another, it would be a mistake to consider that because of this fact the one is a better method than the other. This can only be the case if the two methods have been used without selection of cases. There is no information in the report indicating that comparable groups have been used, and there is no doubt that a strict comparison can only be arrived at by random selection of cases. It seems that clinical selection of method based on experience has been the practice, so that conclusions regarding the relative values of the methods used are not possible. That the value of such an excellent report as this should be limited in this way is good reason for advocating planned clinical experiments to decide such questions.

In the third part of the report the ten-year survivals have been assessed and show a slight decline from the five-year figures. The feature which should be brought home to the medical and lay public is that of 4700 treatable cases of cancer, 54 per cent. are alive after five years with no sign of cancer.

F. Ellis.

S. BRYAN ADAMS, B.Sc., M.B., Ch.B., Ph.D., D.M.R.

As we go to press we learn with regret of the death of Dr. Bryan Adams of Bristol. An Obituary will appear in our next issue.

Vol. XX, No. 233

THE X-RAY DIAGNOSIS OF CHOLESTEATOMA IN THE TEMPORAL BONE*

By Sölve Welin

From the Department of Diagnostic Roentgenology of the Caroline Hospital, Stockholm (Chief Professor Ake Akerlund)

BEFORE I begin to read my paper, I wish to present very hearty compliments to the English Radiologists from your Swedish colleagues, especially from Professor Gösta Forssell, our grand old man, and from my chief, Professor Ake Akerlund, generally considered by us to be the leading Swedish radiologist of to-day. Next, I warmly thank the chairman for his most kind reception.

Personally I feel very honoured indeed to read a paper for this faculty, and I am glad to have met so many excellent English colleagues during my stay here in your hospitable country. I only hope that what I have to say about the X-ray diagnosis of cholesteatoma in the temporal bone may be of some interest to you.

At the Caroline Hospital—one of the two University Hospitals in Stockholm—there is, among other departments, one for ear, nose, and throat diseases, with eighty-nine beds. Here they do about 4000 operations a year on the in-patients and have 35,000 out-patients.

Our X-ray department deals with about 50,000 examinations a year. We are ten radiologists, with Professor Akerlund as chief. As one of the three assistant chiefs there I am responsible for the X-ray examinations of the patients from the Ear clinic.

My lecture is based on the experience I have gained from the large material which has been at my disposal. I may tell you that so far I have examined well over 4000 mastoids.

During my four years at the Caroline Hospital and ten years at the University Hospital in Lund, I have worked intimately with the otologists. They come to me daily to discuss all their films. Further, I have been present at most operations. In that way I have been able to check to what extent the radiological and operational findings have agreed. I have reached the decided conclusion that this close contact between radiologist and clinician is an absolute necessity to get reliable results in these investigations.

I think that the otological X-ray diagnosis is one of the most interesting subjects in the whole field of radiology.

Furthermore, it is a sphere where we radiologists can give the surgeons much help in many of their doubtful cases. I refer not only to the pointing out of more or less pronounced bone changes, but also to those cases where, when the clinician's judgment advises an immediate operation, the X-ray examination on the contrary may strongly advise waiting. On the other hand, one competent X-ray examination can often give a warning in cases where the clinical development has not given cause for anxiety. As an example of this I will point out the cases of so-called masked mastoiditis which, thanks to sulpha and penicillin treatment, are apparently cured clinically with pale tympanic membrane—no fever, etc.—but in which the X-ray examination now and then discloses very serious bone changes.

In cases of chronic otitis we differentiate between those with central perforations of the tympanic membrane and those with marginal. In the former there is hardly any need to think of cholesteatoma, while in the latter it is necessary to bear that affection in mind, whether the perforation is directed upwards towards the attic or backwards towards the antrum.

The clinical symptoms of cholesteatoma may vary considerably. Occasionally there may even be a complete lack of symptoms for a long time. Owing to the liability of the disease to spread to adjoining vital organs, however, an early diagnosis is of the utmost importance.

By itself, cholesteatoma does not produce any typical pathological changes demonstrable in the radiograph—at least, none has so far been observed. Cholesteatoma, therefore, cannot be diagnosed from a radiograph until bone destruction has set in.

The first point, therefore, is to get a detailed anatomical picture of the temporal bone. To be able to do this we need a combination of pictures in different projections. Different investigators use

* Read at a Meeting of the Faculty of Radiologists, October 18th, 1946

different combinations, and often the same projection has very different names in different countries.

I, myself, use a combination of projections following those advocated by the Swede, Runström, supplemented by the symmetrical projection, generally known in England as Towne's projection.

In the projection after Towne, the patient is lying on his back. The chin is a little drawn in and the rays are tilted 35 degrees towards the feet. On the symmetrical radiograph of which we have a line drawing of the one half (Fig. 1) we see the external auditory canal and the tympanic cavity, the antrum, the vertical semi-circular canal, and the internal meatus.

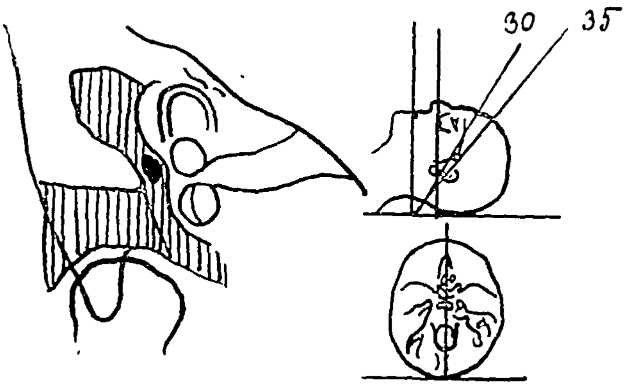


FIG. 1.
To the left: Diagram of the one half of the symmetrical radiograph in the projection after Towne. To the right: Towne's projection.

From the radiograph (Fig. 2) in this position we get a very good idea of the condition in both temporal bones. The picture gives a good general view of the pneumatisation, and especially of the cells, which are situated under the labyrinth and which are not so clearly seen on pictures in any other projection. Furthermore, we see even the smallest differences in the air content between the cell systems of both temporal bones. Also, we get an impression of the calcification in the cell walls and, especially, it is often possible to see clearly any reduction of the calcification in those around the antrum, and this is very important in children. We can also sometimes observe a localised cell destruction, but usually this projection does not permit any real localisation of this. In the cases of completely inhibited pneumatisation we get a good view of the dimensions of the antrum, and often we can gauge

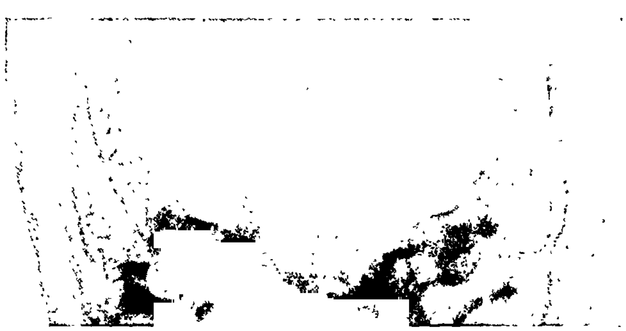


FIG. 2.
Radiograph in Towne's projection.

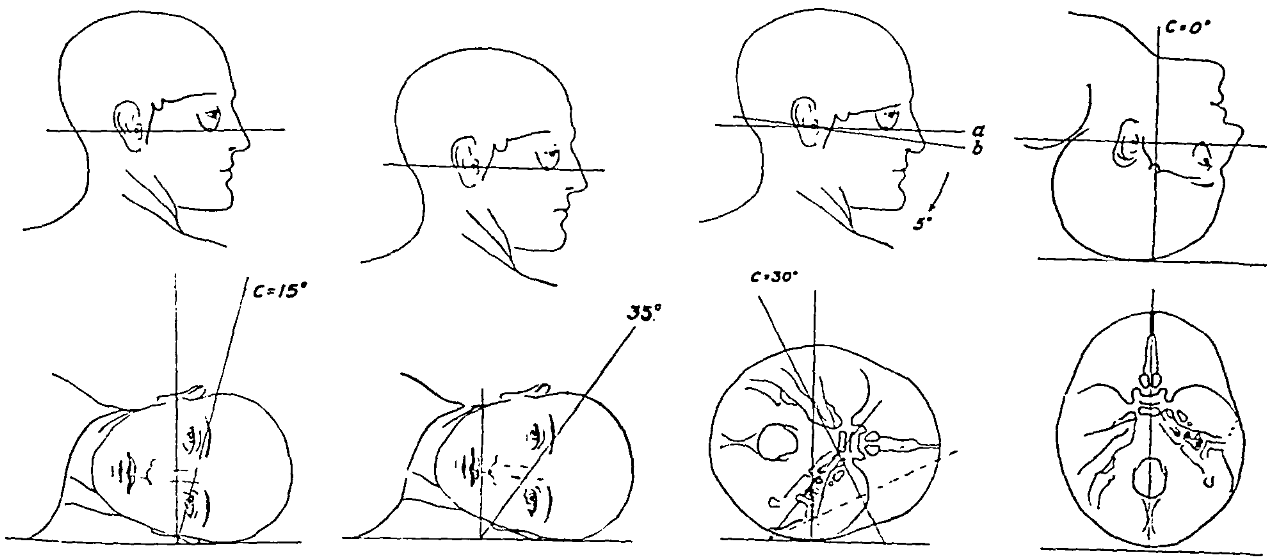


FIG. 3.
Runström's four projections.

the diameter of the aditus, which may be of importance for the diagnosis of cholesteatoma.

In every case we can read off directly the thickness of the cortical bone. This may sometimes be of great importance. In acute cases we may often get a so-called *initial tenderness over the tip of the* mastoid, and in these cases the cortical bone is only of millimetre thickness. Therefore, the tenderness is of little significance. In other cases we can inform

Fig. 4.
Photo of a section through the temporal bone, showing cells on the lateral and superior aditus walls and the rounded upper margin of the strikingly broad posterior wall of the auditory meatus.

the surgeon how far he has to chisel before he reaches the affected area.

On the next picture (Fig. 3) we see diagrams showing the Runström projections. The first projection is a lateral one with a 15-degree tilt towards the feet. In the second projection the position of the patient is the same, but the X-ray beam is tilted, not 15 degrees, but 35 degrees towards the feet.

In these two projections we always take stereo-pictures with the tube shift from side to side.

Runström's third position is a modification of Stenvers' projection. The original Stenvers' view brings, by rotation of the head through 450 degrees, the long axis of the petrous pyramid parallel to the film, and the petrous pyramid is projected through the thin parts of the occiput. Runström simplifies Stenvers' method by having the skull in the true lateral position and tilting the X-ray beam from *behind forwards at an angle of 30 degrees and 5–10* degrees cranially.

The fourth is the well-known standard sub-mentovertical position of the skull.

In order to understand better the complicated anatomy of the first two Runström projections,

Fig. 5.
The same sectioned specimen with a steel wire around the posterior wall.

which we always take stereoscopically, I will first show an ordinary photograph of a sectioned specimen (Fig. 4), which is done in such a way that it agrees with what we see in X-ray pictures in just these projections. Here we see from the front, the attic or the epitympanic recess with its small cells and cell walls and with the ossicles. If we go further back we come to the aditus and, as we know, there is here a little difference in interpretation between otologists and radiologists. The otologists consider that the aditus is only a hole, while we radiologists see it as a *real channel. This is due to the fact that* we have the patient in a lateral position and the

external auditory canal is not at right angles to this plane, but oblique. Therefore, the X rays fall, not parallel, but obliquely with regard to the dense posterior wall of the external auditory canal. This looks in consequence astonishingly thick—and has a rounded upper border—and the aditus appears thus as a channel. This is well illustrated by Fig. 5. It is the same sectioned specimen but now with a steel wire around the posterior wall. Furthermore, I want to call special attention to the cell walls, which we see around the aditus ad antrum, and we see also the cells around the antrum and downwards into the tip of the mastoid.

Let us now look at the radiographs. Fig. 6 shows a radiograph with the X-ray beam tilted 15 degrees behind this line are in the posterior zygomatic root. In this case the cells extend forwards into the posterior zygomatic root. The cells in the attic, aditus ad antrum, and squama are clearly seen, and also the cells downwards in the tip of the mastoid and over the sinus.

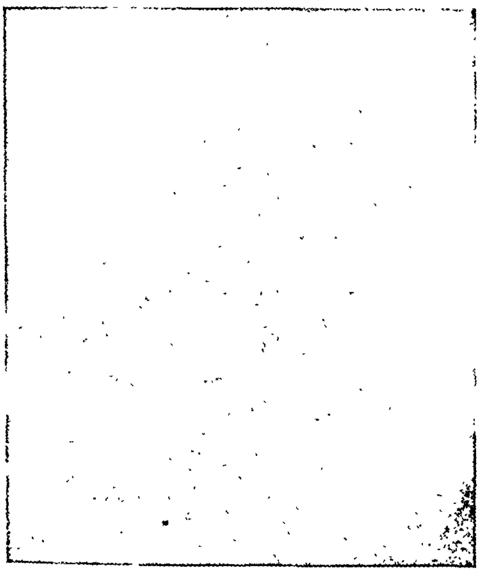


FIG. 6.
Radiograph in Runström's first projection.

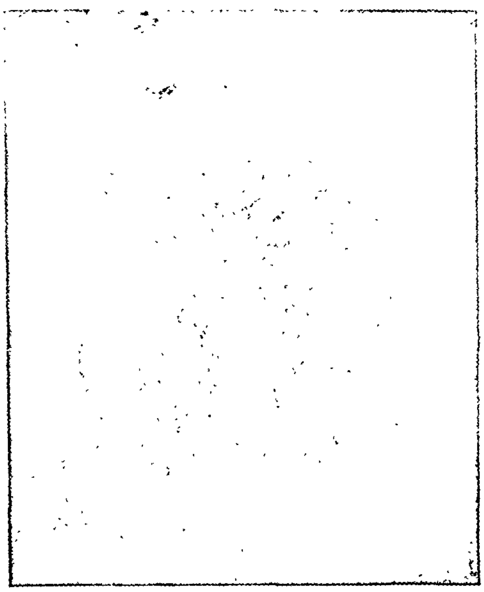


FIG. 7.
Radiograph in Runström's second projection.

towards the feet. We see the cells in the attic. We cannot always estimate distinctly the borders of the aditus on pictures in this projection. Furthermore, we see the cells around the antrum, in the tip, over the sinus, up against the squama, and the sino-dural angle with its cells. These were earlier called "angle of death" cells.

In the picture (Fig. 7) with the beam tilted 35 degrees towards the feet, the cell system comes into view differently. We can now see better if there are any cells in the zygomatic bone. If the cells extend forwards in front of an imaginary vertical line through the top of the mandibular joint, they are situated in the anterior zygomatic root and the cells

If we think once more of the aditus ad antrum, we find that the lower border is sometimes difficult to demonstrate.

Many investigators say that this border on the X-ray picture coincides with the upper border of the labyrinth. Therefore we would not be able to differentiate the two borders. But this is not right. In order to demonstrate this I have put in one steel wire in the upper semicircular canal and another round the posterior wall of the external auditory canal, and this border constitutes the floor of the aditus. On this radiograph (Fig. 8), with the beam tilted 15 degrees towards the feet, both the steel wires coincide exactly.

On the radiograph (Fig. 9), with the beam tilted 35 degrees towards the feet, we can clearly differentiate them from one another. We see again how thick—in the radiograph—appears the really thin posterior wall of the external auditory canal.

Notice how the posterior wall runs slightly into the external auditory canal in radiographs in this projection, which can sometimes make the demonstration of this structure easier.

Now for the radiograph (Fig. 10) employed by Stenvers. According to Runström we tilt the beam 10 degrees cranially in order to get the tip of the mastoid below the skull and at the same time are able to guage the whole petrous bone. On this radiograph we can see whether there are cells in the petrous bone and decide the diameter of the internal meatus.

Furthermore, we use the axial projection (Fig. 11), and the chin must be so much drawn forwards that we can get the external auditory canal and the tympanic cavity clear of the shadow of the mandible.

Fig. 8.
Picture in Runström's first projection. A steel wire in the upper vertical semicircular canal, and another around the posterior wall of the external auditory canal, coincide exactly.

Fig. 9.
Picture in Runström's second projection. In this projection we can differentiate both the steel wires from one another.

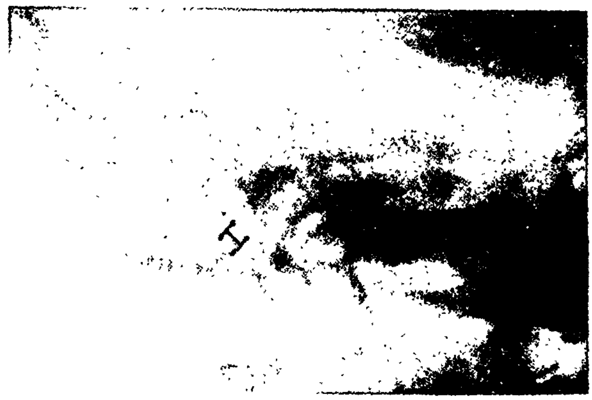


Fig. 10.
Radiograph in Runström's third projection.

We can see here whether there is exostosis of the external auditory canal and, as the most important point, whether the ossicles are normal or not. It is true that the ossicles have not any deciding consequence in the differential diagnosis between chronic otitis and cholesteatoma, but often we can diagnose osteitis in the ossicles.

The X-ray method of diagnosing cholesteatoma was originally considered easy; experience, however, has shown that this is by no means so, but may rather—as in acute otitis—involve great difficulties. This is especially considered to apply to cholesteatoma situated in pneumatised temporal bones.

The sharp definition, angularity, and polygonal shape of cholesteatoma cavities, their occurrence in temporal bones with reduced pneumatisation, and

Fig. 11.
Radiograph in Runström's fourth projection. The ossicles are clearly seen on both sides.

—as a sign of proliferative reaction—a linear calcareous zone between them and the surrounding bone tissue, have hitherto been held to be characteristic, but we know now that there are also other characteristics.

Several research workers have concurrently strongly emphasized that in these cases the adequacy of X-ray examinations must not be over-rated, and that only a positive X-ray finding constitutes definite proof; a negative result of a radiological examination does not justify the exclusion of cholesteatoma.

We differentiate between cholesteatoma according to its site: external auditory canal, attic, aditus, the eustachian tube and antrum.

Here (Fig. 12) is a typical case of a cholesteatoma in the external auditory canal. Quite frequently the otologists see cases of cholesteatoma in the external auditory canal, but such patients rarely come to the X-ray department. In this case, however, the clinicians could only get small flakes away and they suspected that the cholesteatoma might continue into the tympanic cavity. Therefore, the pictures were sent to me—the patient was lying in a hospital in the country. In this picture you see that the external auditory canal is much bigger on the affected side than on the other. The cholesteatoma has produced a superficial destruction in the floor and in the posterior wall. The cell system has normal air content and the cell walls are of normal density.

In the axial radiograph (Fig. 13) we see the superficial destruction of the posterior wall in its full extent. In the tympanic cavity nothing pathological is to be seen. The ossicles are situated normally. Even in this picture we find no sign of pathological changes in the cells. The cholesteatoma was thus limited to the external auditory canal only. The otologist performed a conservative radical operation.

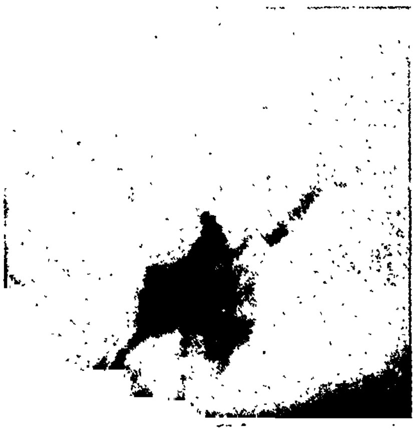


FIG. 12b.

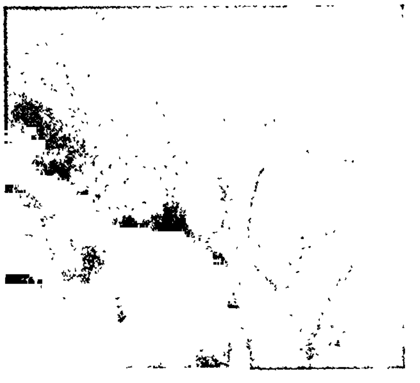


FIG. 12a.

Radiographs in Runström's second projection. The external auditory canal is enlarged through destruction in the floor and in the posterior wall. (*a*) The affected side. (*b*) The healthy side.

He found normal conditions in the cell system with pale mucous membrane and hard cell walls and a destruction in the posterior wall as shown by the X rays.

Now for the cholesteatoma in the attic. The radiological changes here differ with the localisation of the destruction caused by the cholesteatoma in the tympanic recess.

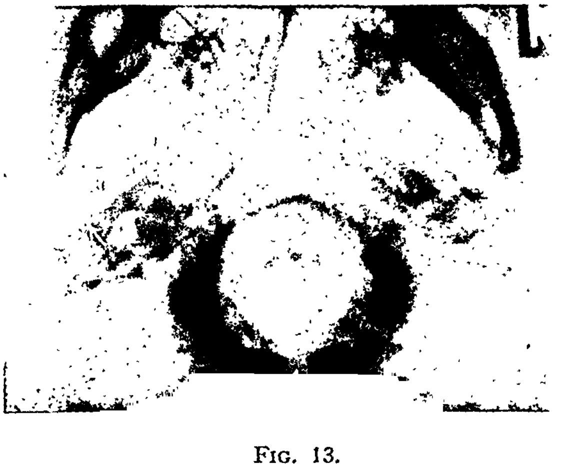


FIG. 13.
Axial radiograph of the same case. Superficial destruction of the posterior wall between the two arrows. The third arrow points out the ossicles.

According to Mayer, three fundamentally different types can be distinguished.

Fig. 14 shows two line drawings. On the left is a frontal section through the external auditory canal and the tympanum showing a part of the tympanic membrane, the epitympanic recess with the ossicles, destruction of the lateral wall; sometimes it grows upwards against the ceiling of the attic and causes destruction there. Thirdly, it may grow backwards against the aditus and here cause a more or less pronounced destruction of the walls of the aditus.

If the cholesteatoma destruction appears in the

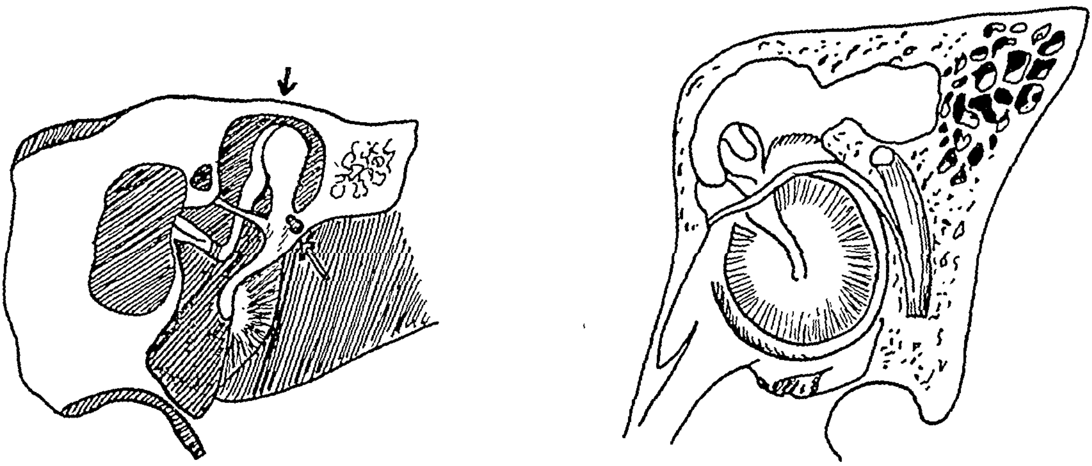


FIG. 14.
Diagrams of the epitympanic recess.

and some cells of the lateral attic wall. The arrow in the external auditory meatus marks the place of the attic fistulæ, the arrow at the top points out the floor of the middle fossa.

On the right is a section parallel to the mastoid plane, showing the epitympanic recess, the tympanic membrane, the aditus ad antrum, the posterior wall with the facial nerve, the antrum, and also some cells in the mastoid process.

Sometimes the cholesteatoma causes a localised

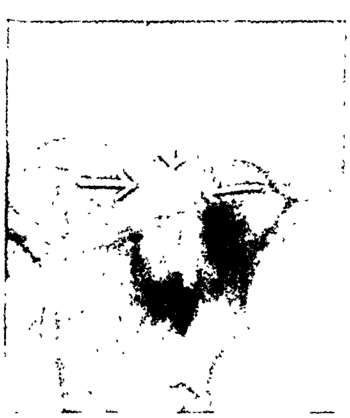


FIG. 15.
Attic cholesteatoma with destruction of the lateral wall.

lateral wall of the epitympanic recess, close to the fistula, it produces very characteristic changes in the X-ray picture. These take the form of well-defined spikelike or rounded defects in the lower margin of the attic, which may vary considerably in size. Fig. 15 shows such a case.

The cholesteatomata sometimes develop upwards to the floor of the middle fossa and produce destructions there. In the axial picture, a distinctly circumscribed thinning is then discernible in the region of the tympanum. In the central part we see the small remnants of the ossicles, and this is a typical finding (Figs. 16 and 17).

In cases of cholesteatomata developing posteriorly towards the aditus, the latter may become pathologically enlarged. We see a well-defined destruction, the margin of which is convex backwards to the aditus, which is enlarged. The cell walls in the aditus are destroyed and, especially stereoscopically, we get the decided impression of destruction. Apart from this destruction in the lateral and superior wall of the attic, the inner border of the posterior wall of the auditory canal is planed down (Fig. 18).

It must not be forgotten, however, that in these cases a high attic with smooth and even surfaces, in

which there are no ossicles, may look very like a cholesteatomatous attic.

The most important and at the same time most common radiological indication of cholesteatoma is in our opinion the pathological enlargement of the aditus. In some cases the change consists merely in

FIG. 16.
Attic cholesteatoma with a destruction towards the roof of the middle fossa of the skull.

a hardly demonstrable planing down of the innermost portion of the posterior wall of the auditory canal, or in an infinitesimal destruction of the lateral

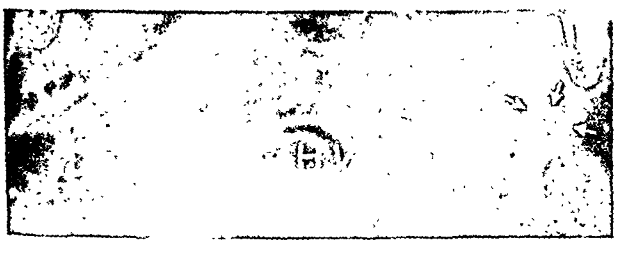


FIG. 17.
Attic cholesteatoma with a destruction towards the roof of the middle fossa of the skull.

and superior walls of the aditus (Fig. 18). In other cases the destructions of the aditus are more pronounced, and in Fig. 19 the changes include also the antrum cavity. The enlargement of the aditus is also to be seen on pictures in Towne's projection, as Fig. 20 shows.

In most cases the cholesteatoma cavities are, generally speaking, rounded, and thus not of the angular form previously said to be characteristic of cholesteatoma destruction. In other cases the inner portion of the posterior wall of the auditory canal may be almost completely destroyed, permitting the cholesteatoma to be discharged directly into the external auditory canal; this may be called a spontaneous radical operation (Fig. 23a).

In practically half of our cases cholesteatomata were diagnosed on changes in the aditus alone.

But these changes do not permit any conclusions to be drawn regarding the extent of the cholesteatomata, as these may reach far forward into the tympanum or backwards into the antrum without causing any further radiological changes.

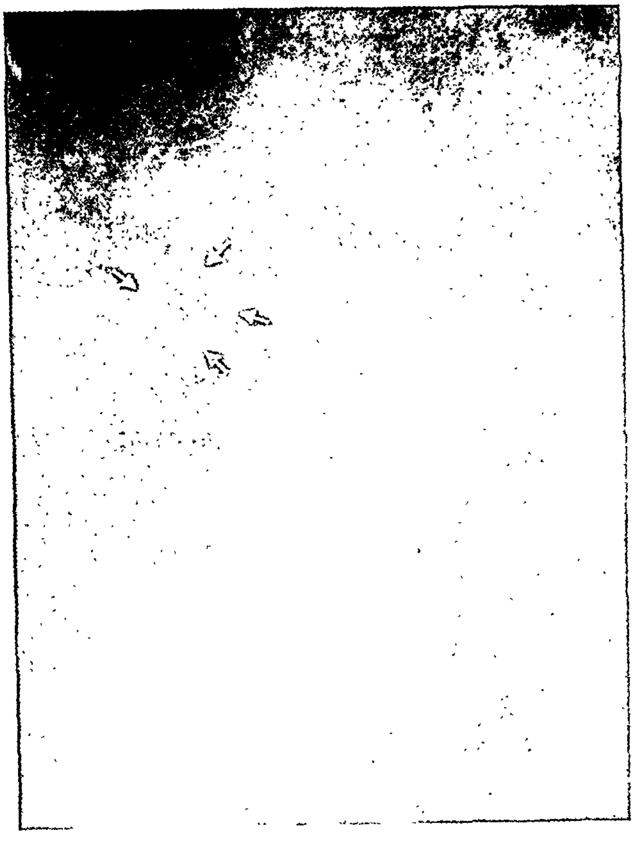


FIG. 18.
Attic cholesteatoma developing posteriorly towards the aditus, destroying the cell walls and producing a pathological enlargement.

The cholesteatomata sometimes develop downwards to the bottom of the tympanic cavity and the eustachian tube. The latter may become pathologically enlarged. We see in these cases a pathological dilatation of the tube with sharp outlines, and this is also a very typical finding (Fig. 21).

We now turn to the cholesteatoma of the antrum.

From the point of view of X-ray diagnosis we differentiate between cholesteatomata in non-pneumatised temporal bones and in pneumatised temporal bones. In the former a diagnosis can not as a rule be made by means of X-ray examinations until the destruction has become rather extensive—unless there is also a pathological enlargement of the aditus. In such cases a correct and early diagnosis will largely depend on the experience of the

examiner, as the size of a normal antrum may vary considerably. An antrum which by one doctor is considered enlarged may by another be thought normal.

A radiograph in Towne's projection (Fig. 22) demonstrates a case of cholesteatoma of the antrum in a non-pneumatised cell system. Holmes, in America, used an almost identical projection. In a paper, published in 1938, he pointed out that antrum enlargement can be diagnosed earlier with this projection than with any other. He was able to demonstrate an enlarged antrum by this projection in 165 cases, in all of which the operation disclosed cholesteatomata destroying bone.

In Fig. 22 we see a pathologically enlarged cavity of distinctly rounded outline. In this case there is no doubt that it is a pathologically enlarged antrum.

Here is a radiograph (Fig. 23) of the same patient in Runström's second projection with the beam tilted 35 degrees towards the feet. The distinct

Fig. 19a.

Fig. 19b.
(*a*) Pathological enlargement of the aditus due to a planing down of the innermost portion of the posterior wall of the external auditory canal. (*b*) The healthy side.

Fig. 20.
Pathological enlargement of the aditus is also visible on pictures in Towne's projection.

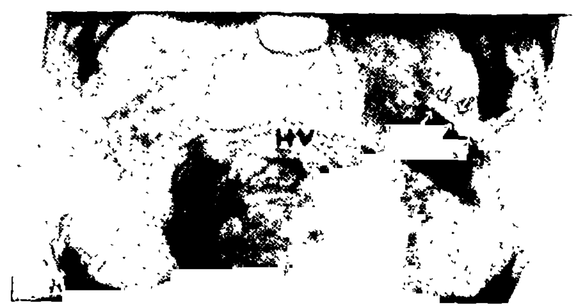


Fig. 21.
The cholesteatoma has produced a pathological enlargement of the eustachian tube.

Fig. 22.
Picture in Towne's projection. Antrum cholesteatoma in a non-pneumatised mastoid bone.

margin of the cavity can be observed even more clearly. Note the characteristic linear calcareous zone, which according to some doctors is a result of tissue reaction to the irritation of some foreign body, something like the formation of new bone round a bullet or metal pin.

FIG. 23a.

FIG. 23b.
The same case in Runström's second projection. (*a*) The affected side. (*b*) The healthy side.

In this case the inner portion of the posterior wall of the external auditory canal has, moreover, been so extensively destroyed that a considerable pathological enlargement of the aditus can be seen, which further supports the diagnosis of cholesteatoma.

If the cholesteatoma in the antrum is situated in a more or less pneumatised temporal bone, the difficulties of an X-ray diagnosis may be just as great.

Should the cholesteatoma cavity be small, the X-ray method of examination may prove a complete failure, provided there is not also a pathological enlargement of the aditus. Such a pathological enlargement may thus be the only change permitting a diagnosis of cholesteatoma in these cases.

If the destruction is large it may be difficult to differentiate between cholesteatoma and an abscess cavity, unless the aditus is pathologically enlarged. From the point of view of the differential diagnosis it is generally pointed out that the margins of cholesteatoma cavities are as a rule more distinctly circumscribed than those of abscess cavities. Changes in sclerotic temporal bones also favour a diagnosis of cholesteatoma. In addition, abscess cavities are not common, although occasionally met with in cases of chronic otitis. There are consequently no symptoms typical of one change or the other in the X-ray picture, and cases therefore occur in which no certain radiological diagnosis can be made.

In conclusion I realise that the diagnosis of the chronic mastoid is a difficult one, but I think that the methodical use of the projections shown by me will facilitate an earlier diagnosis and will prove itself more reliable. I hope that my little contribution may be of some help to you in your difficulties.

REFERENCES

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In these references will be found a complete review of the literature.

CHOLESTEATOMATA OF THE TEMPORAL BONE*

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A CHOLESTEATOMA of the mastoid requires two conditions for its formation: firstly, a low-grade, chronic infection and, secondly, a diplœtic or poorly pneumatised mastoid.

The condition is associated with a long-standing history of a copious and foul aural discharge.

Almost all middle-ear infections commence in the naso-pharynx and spread up the Eustachian tube into the middle ear. The accompanying diagram, though not intended to be anatomically correct, shows the path which these infections take (Fig. 1).

In a cellular mastoid, the infection spreads from the middle ear, through the aditus ad antrum into the mastoid antrum and, thence, into the mastoid cells. In an acellular mastoid, if the infection is of some virulence, the diplœtic bone is infiltrated by the organisms and diffuse bone infection takes place; but if the invasion of the acellular mastoid is by an organism of low virulence, then a much slower process takes place. The normal mucosa of the middle ear is destroyed and gradually replaced by epidermal cells, either by extension of the epidermis from the external auditory canal through the ruptured drum, or by cellular metaplasia. These epidermal cells are continually being desquamated by the infection and replaced, and they collect in a slow, but constantly enlarging mass in the epitympanic recess, the aditus ad antrum or the mastoid antrum. The organism is not sufficiently virulent to infiltrate to any extent the surrounding acellular bone, but it gradually softens it by infection and erodes it by the pressure of the constantly enlarging mass of dead cells.

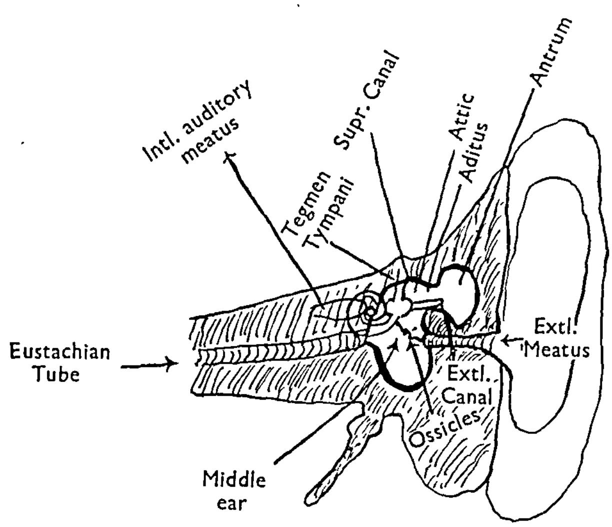

Fig. 1.

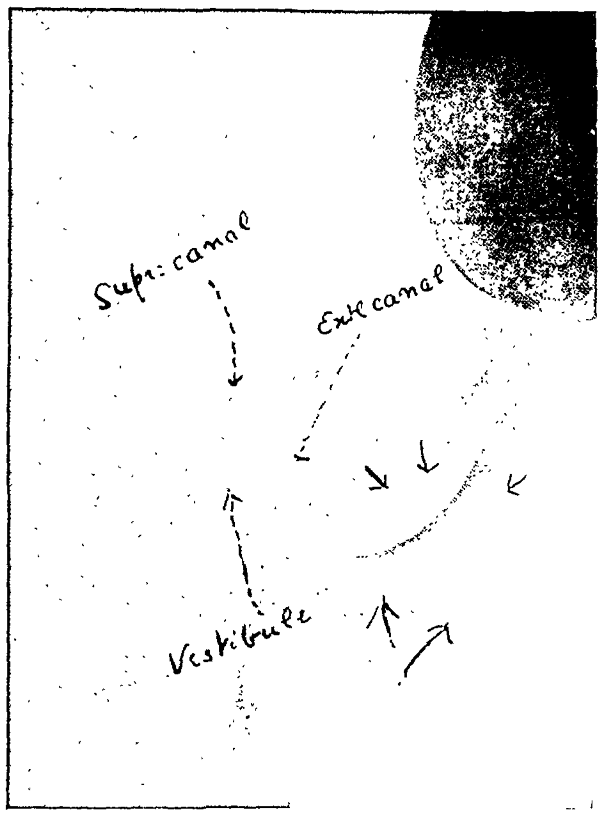

Fig. 2

Large cholesteatoma

A thin, protective ring of sclerosed bone is frequently seen around the expanding "tumour" (Fig. 2), but where the mastoid is of the sclerotic type, or where a good deal of sclerosis has taken place surrounding the cholesteatoma, this ring may be concealed in part or entirely (Fig. 4).

It is obvious that until the pseudo-tumour has

* Read at a meeting of the Faculty of Radiologists, October 18th, 1946.

eroded the walls of the cavity it occupies, appreciably beyond the normal limits, there will be no radiological evidence of its presence. Frequently, because of its comparatively small size, the signs of erosion will first be seen in the aditus ad antrum.

As the cholesteatoma erodes more and more bone, a time may come when perforation of the containing wall occurs. The diagram indicates the points at which this perforation may occur. In the first place, perforation may occur through the tegmen tympani into the middle fossa of the skull, or it may perforate into the external auditory canal. The tip of the external canal of the labyrinth, covered by the labyrinthine capsule, projects into the wall of the mastoid antrum, and perforation may occur here with a resulting fistula (Figs. 3 and 5).

Though cholesteatomata are by no means uncommon, they may be difficult to detect in a mastoid of the sclerotic type or in a mastoid in which a good deal of sclerosing osteitis has occurred around the small periantral cells, which not infrequently occur in an otherwise acellular mastoid. Usually, however, with the aid of experience and good radiograms, they can be detected if the radiologist knows what to look for.

One sees an area of lesser density than the surrounding bone, but not so transradiant as a solitary air-cell of the same size would be. It is usually in the immediate neighbourhood of the mastoid antrum or attic, and it may encroach on or perforate the posterior wall of the external auditory canal. This area of bone destruction is frequently smooth in outline and of oval or rounded shape, but it may occasionally be irregular in shape, particularly in those mastoids where a few scattered cells are present. As mentioned above, a thin line of sclerosed bone may be seen in some cases surrounding it wholly or partly. In the postero-anterior oblique projection this area should be looked for in the neighbourhood of the apex of the external canal. In the lateral oblique view it is seen in the area bounded above by the tegmen tympani, and in front by the

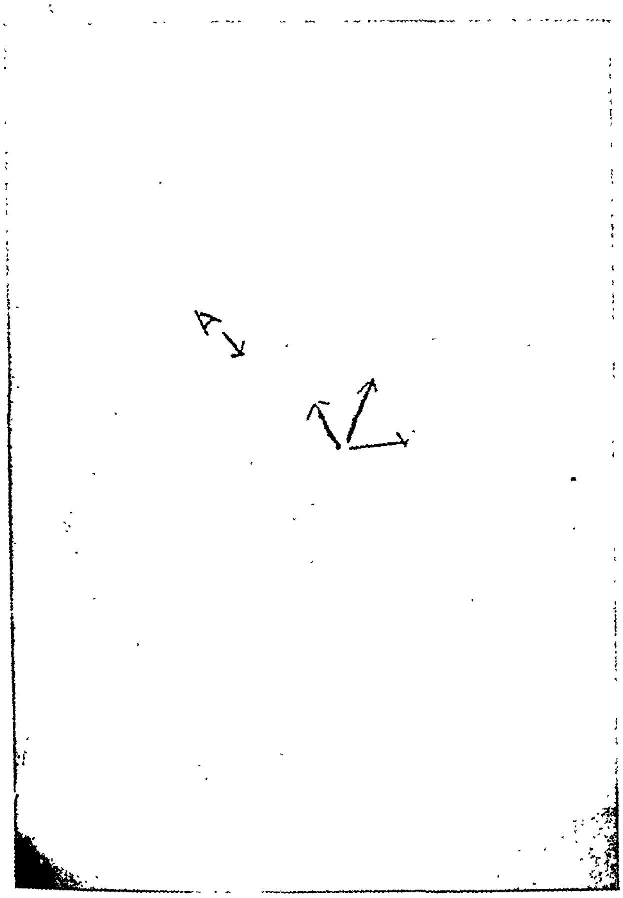

Fig. 3
Same case as fig. 2. Note attic perforation at A.

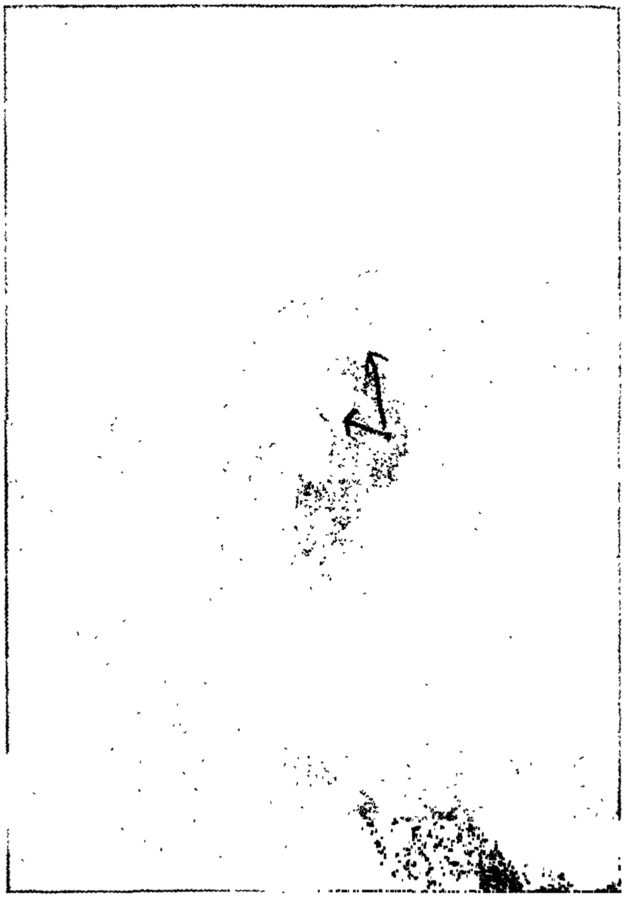

Fig. 4.
Cholesteatoma.

upper part of the posterior wall of the external auditory canal. Perforation of either of these structures may be shown as actual gaps in the bone, but more usually as areas of local rarefaction.

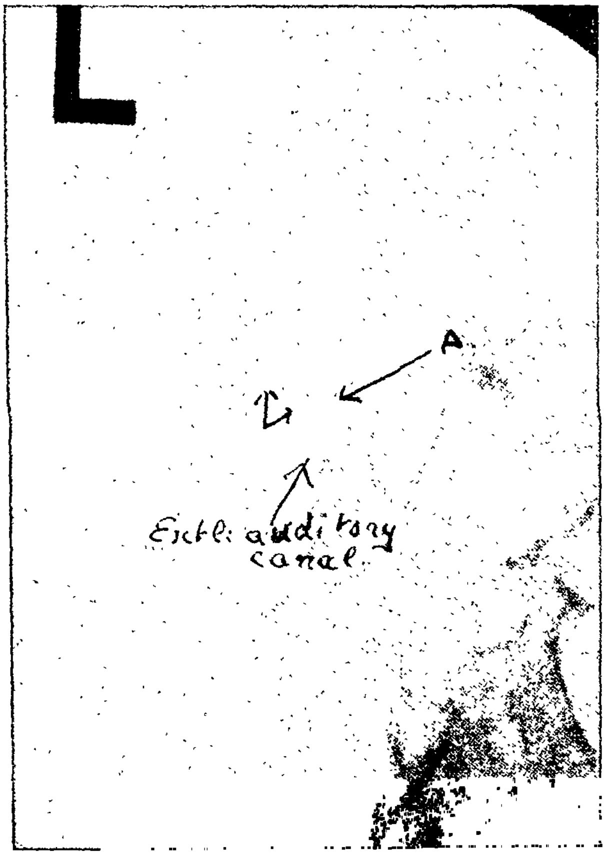

Fig. 5
Cholesteatoma with perforation into external auditory canal.

Fistulæ of the external canal of the labyrinth are often impossible or difficult to detect because they may occur at any point on the convexity of the apex of the canal, which point may not be tangential to the rays, and the fistula tends to be concealed by the marked density of the labyrinthine capsule. When a fistula is visible, it is seen as a funnel-shaped defect in the labyrinthine bone close to the apex of the canal.

A cholesteatoma is distinguished radiologically from a mastoid abscess, firstly, by its location in the immediate neighbourhood of the antrum or attic, whereas an abscess is more common in the peripheral zone; secondly, a cholesteatoma occurs almost invariably in an acellular or poorly pneumatised mastoid, whereas an abscess may occur in either a cellular or diplœtic mastoid, but more commonly in the former. Cholesteatoma is distinguished from a solitary air-cell by its location, by the fact that examination of the opposite mastoid will reveal no corresponding cell, and also by the fact that the bone surrounding a cholesteatoma shows reactive changes, and a cholesteatoma is usually more opaque than an uninfected cell of corresponding size would be.

Confusion with an operation cavity should not occur if the clinical history has been taken, as it invariably should be.

STANDARDISED RADIOLOGICAL PELVIMETRY
IV. INTERPRETATION OF PELVIMETRY

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RADIOLOGICAL pelvimetry is a means to an end; that end being to assist the obstetrician in his conduct of labour by analysis of the mechanical relations between head and pelvis. The principal difficulties encountered during labour are basically of a mechanical kind, and radiological pelvimetry represents the only reliable method of assessing the mechanical factors involved before labour commences. It should not be necessary here to repeat the time-honoured apology that the bony pelvis is only one factor in labour. This is clearly recognised. Dippel (1938), speaking of the scope of pelvimetry, says: "It may be argued that there are so many factors in labour, namely, the size of the baby and the character of the uterine contractions, that an approximation is enough. We do not agree with this viewpoint. The fact that these other factors are difficult to evaluate accurately makes it all the more important, in cases of contracted pelvis, that we should have as precise information as possible concerning the one factor we can measure with precision." Thoms' view is that "knowledge of available pelvic space and of pelvic conformation, as shown by prenatal röntgen pelvimetry, has eliminated certain trial and error methods of obstetric procedure and placed operative measures on a sounder basis".

If the fœtal head had the characteristics of a cannon-ball—perfectly round, incompressible, and of standard size—the interpretation of pelvimetry would be comparatively simple. It would then be certain that, no matter how strong the pains or how favourable other circumstances, the head would not pass through a pelvis of which one or more principal diameters were less than that of the head itself. Pelvimetry would then be reduced to a matter of measuring a few selected diameters, and basing a prognosis entirely on the comparative size of these diameters and that of the standard fœtal head.

The fact that the fœtal head has not these characteristics very materially complicates the interpretation of radiological pelvimetry, but does not make it impossible. Variations in the size and compressibility of the skull may mean that it is impossible to predict with absolute certainty the mechanical outcome of labour, but it does not mean that such a prediction cannot be attempted with reasonable assurance. Radiological pelvimetry is in the position that it is almost alone amongst the problems of diagnostic radiology in that interpretation is not based upon any of those standard criteria which make the diagnosis of such lesions as fracture and duodenal ulcer so certain and clinically so valuable. The real reason why these criteria are not available seems to me to be that there have not yet been reported sufficient studies in which the course of labour has been correlated with the features of the maternal pelvis. We do not, in effect, know what average allowance must be made for soft parts, moulding, and strength of pains. There are some notable exceptions to this general statement, such as the papers of Nicholson, Ince and Young, Williams, Williams and Phillips, Thoms, and Weinberg and Scadron. The first two of these papers represent a statistical study of various features of the pelvis and of certain external measurements correlated with the course of labour: the latter are valuable descriptions of the author's experiences in the interpretation of pelvimetry. To me these papers still leave a gap to be bridged. Only that of Weinberg and Scadron state in other than general terms upon what grounds prediction is based. This common failing can be illustrated by reference to the paper of Williams and Phillips. These authors state their aim to be "a frank attempt to assess the reliability of prediction of the course of labour from ante-natal radiological examination alone". Using frontal and lateral projection reconstruction charts, upon which are superimposed circles representing the fœtal skull or tracings of the skull itself, they have offered predictions of the course of labour in a large series of cases and have checked these predictions against the subsequent clinical course. They report that their prediction of normal labour was substantially correct in 204 of 206 cases (99·4 per cent.), and they conclude with good reason that if normal delivery is forecast, the prediction may be accepted with assurance. In borderline cases the prediction was substantially correct in 11 of 24 cases (46 per cent.),

and in abnormal cases in 13 of 23 cases (56·6 per cent.). These figures, though not so striking, are so almost wholly because of undue pessimism, and the authors feel that they were almost never at fault in failing to predict a mechanical difficulty subsequently encountered. In all, a prediction which accorded completely with the subsequent course of labour was offered in 89·4 per cent. of cases; and the authors think that with increasing experience, especially in the borderline cases, this percentage can be increased.

It is clear that if radiologists in general were able to predict the course of labour with anything approaching this accuracy, radiological pelvimetry would be much more widely used and therefore of much greater general benefit than is at present the case. But such predictions are utterly beyond the hope of the general radiologist. Williams and Phillips are experienced workers, specialists in this field, and have the advantage of working in a special maternity hospital. The general radiologist, seeing only a case or two a month, cannot be expected to achieve such results. Yet it appears to me that the general radiologist could at least approach such accuracy were the basis upon which prediction is based fully explained and formulated. There is nothing mysterious or inherently difficult in measuring the pelvis: the difficulty arises in the interpretation of the measurements.

It will be my main task in this paper to attempt to establish some basis for prediction by correlating the course of labour with certain features of the pelvis, and by trying to assess what particular features are the most reliable guides to the course of labour. I do not mean to imply that the Williams and Phillips reconstruction charts are in any way inferior; their figures speak for themselves, and their methods may well prove to be the best. My own approach merely happens to have been along different lines. In a previous paper, I reported a method of measuring the pelvic outlet, and showed how, by using the available posterior sagittal of the outlet for prediction, a positive prognosis could be offered in 70 per cent. of cases. I have used the same basic method of analysis in dealing with the inlet and mid-plane of the pelvis; but in view of Williams and Phillips' very carefully controlled work, I feel that I should offer some further comments upon my method of dealing with my own material.

It must be emphasised that my aim is not to test the accuracy of my own predictions (as Williams and Phillips have done) but to correlate the course of labour with the size of certain pelvic characteristics. For this purpose my material has been analysed in the following manner. The report on the course of labour, provided by the practitioner conducting the labour, has been examined, if possible without reference to the radiological report, and the case has been classed as either normal or abnormal. Nicholson (1938) used as his criterion of abnormal labour "any interference with normal labour necessitating a general anæsthetic", although he fully recognised that this criterion resulted in many cases being classified as abnormal in which there was no suggestion of any bony disproportion. I have been at pains to avoid what I feel is an approach which greatly detracts from the value of Nicholson's otherwise very valuable paper. Labours have been classed as normal for the purposes of this study only if they met the following requirements:

1. The child weighed between 6½ and 8½ lb.
2. There was no evidence of abnormal moulding of the head.
3. The first stage of labour occupied no more than 20 hours and the second stage no more than 4 hours.
4. An operative procedure may have been employed, but it was for a condition definitely *not* related to disproportion.

The abnormal cases have been further subdivided in two ways. In the first place, an attempt has been made to assess the level or levels in the pelvis at which disproportion occurred, inlet, mid-plane, or outlet. This appeared to be a necessary corollary of the argument set out above, that we are concerned only with disproportion. It would not be proper, for instance, when considering the effect of the conjugate on the course of labour to include as abnormal in this respect a case which had required only low forceps for mild *outlet* disproportion. Such a case is clearly a normal case at the level of the inlet, and the application of low forceps at the outlet is not relevant to consideration of the inlet. There were naturally a number of cases in which disproportion existed in varying degree at all levels. The second sub-division involved "weighting" the abnormal cases. It appeared that if one was to attempt to fix the level at which disproportion existed, one should also allow in some measure for the degree of disproportion encountered. It is

certain that, in a statistical analysis, more weight should be attached to a case in which there is absolute disproportion necessitating Cæsarean section than to one in which the only evidence of disproportion is some delay in the engagement of the head. The former case is clearly more significant. All abnormal cases were therefore weighted by being sub-divided into the following three categories and weighted 1, 2, and 3, respectively:

i. Cases in which evidence of disproportion was minimal (*e.g.*, moulding of the head in a 5½-lb. child was regarded as minimal evidence). Weighting 1.
ii. Cases in which there was definite disproportion, but in which a normal child could be delivered *per vias naturales* (*e.g.*, forceps deliveries, unless due to delay on the soft tissues of the perinæum, were regarded as definite cases). Weighting 2.
iii. Cases in which delivery P.V.N. was impossible. Weighting 3.

In practice, this method of weighting has resulted in some cases being classed as abnormal which were in fact normal. Thus, a moulded head in a 5½-lb. child delivered in normal time without assistance was regarded as a mildly abnormal labour, since it was inferred that a normal 7½-lb. child would probably have required assistance or, at least, that labour would have exceeded the normal standard limits of time. The converse is also true, that some abnormal labours were regarded as normal. Thus, a 9½-lb. post-mature child with marked delay in engagement of the head, but delivered without assistance, would be classed as normal, because it would be supposed that a normal head would have engaged without delay. It will be seen that the weight of the child was always taken into consideration when weighting. This was done deliberately because of my personal conviction that estimates of head size, unless extreme care is taken and, perhaps, not even then, are not sufficiently reliable for practical purposes. This seems to be a generally accepted opinion, and it therefore seems necessary to offer predictions based upon what may be expected to happen to the *normal standard* head rather than to the head of the case one is actually concerned with. The prediction based on this standard head may later be modified if there is reason to suppose that the particular head varies significantly from the standard.

This method of dealing with my material will, I feel sure, leave me open to criticism, but the method evolved has seemed to me to be the only one whereby a full and individual analysis of the course of labour in each case could be made in a manner suitable for statistical treatment. Indeed, the analysis has not been rendered any easier by the fact that I have had to rely for descriptions of labour upon details provided by the practitioner in charge of each case. It is natural that the standard of obstetrics practised is variable, and in some cases mental allowances have had to be made for known idiosyncrasies of the various practitioners.

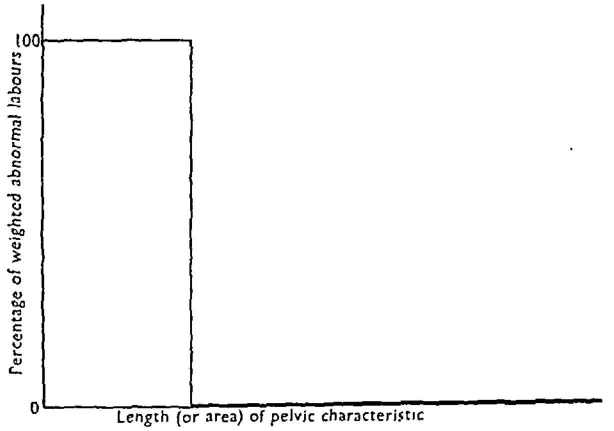
The correlation between labour and the dimensions of the pelvic characteristics has been summarised graphically, the graphs showing the variation of the pelvic characteristic against the percentage of weighted abnormal labours. Each graph is self-explanatory and will require but little description, but it may be as well to call attention to some features common to all the graphs.

It should first be noted that owing to the weighting of the abnormals, the percentage on the graph is not necessarily the percentage of cases. Thus, a reading of 50 per cent. on the graph might represent one abnormal case weighted 3 and three normal cases; or it might represent three abnormal cases weighted 1 and three normal cases.

In reading the graphs it is necessary to keep the aim of this study in mind. We are trying to determine which pelvic characteristics are of most use in predicting the course of labour, and to determine to what extent each is reliable. If we consider again the head to be possessed of the properties of a cannon ball, we would obtain a graph such as illustrated in Graph 1. The features of such a graph would be a flat upper section on the left, representing abnormal labours associated with diameters below the critical level, which would be the diameter of the standard skull. At the bottom, on the right, would be another flat section representing normal labours with diameters above the critical level. The two sections of the graph would be separated by a vertical line, at the critical level. The practical value of such a graph is clear. It allows a definite prognosis to be given in every case: there is no section on the graph representing *possibly* abnormal labours, and the flat section of the graph represents 100 per cent. of the cases. This graph is the theoretical ideal allowing 100 per cent. positive prognosis. The graphs which

follow should be compared with Graph 1. The main difference is that each graph has three sections: flat upper left and bottom right sections as in the ideal graph, but a dividing line between the two sections, which is not a vertical line but a slope. This slope occupies a variable portion of each graph. It represents the values of the pelvic characteristic associated sometimes with normal and sometimes with abnormal labour, *i.e.*, it represents the cases in which a positive prognosis cannot be given. The shorter and steeper the slope the more nearly does the graph resemble the ideal graph, and the greater therefore its practical efficiency. A measure of the efficiency of each graph is the percentage of the total *number* of cases represented on the flat parts of the graph, for this will be the percentage of cases in which a definite prognosis can be given.

Series of graphs to show the results of correlating the percentage of weighted abnormal labours at the appropriate levels with the variations in selected pelvic characteristics.



Graph 1.
"Ideal" graph to show characteristics which would allow positive prognosis in every case. Efficiency, 100 per cent.

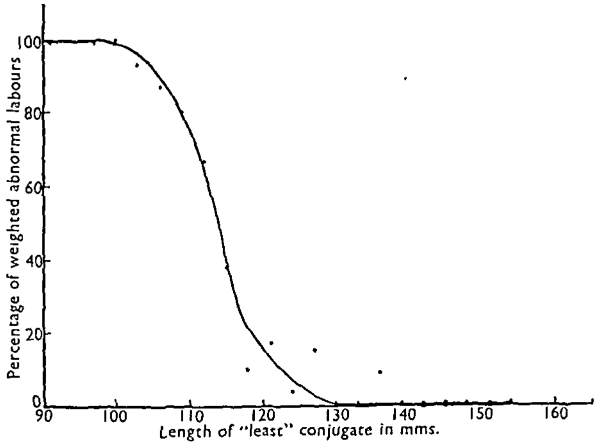
Two other features which may be noted about each graph are the range and the critical level. The range is of interest because the greater the range the more likely is there to be a difference between normal and abnormal diameters. As for the critical level, Nicholson used this term to define the level at which there was a 50 per cent. change of vaginal delivery being impossible. Applied to these graphs, it is the level at which there is a 50 per cent. chance of labour being abnormal to some degree: it has no relation to the question of vaginal delivery. It may be expected, therefore, that the critical levels here will be substantially higher than those determined by Nicholson.

Inlet

The characteristics of the inlet to be considered as possible bases on which to offer prognoses are the "least" conjugate (as defined in Part I), the transverse, the brim area, and the brim index. The brim area has been computed according to the method used by Nicholson (1938).

Conjugate (Graph 2)

Graph 2 shows the percentage of weighted abnormal labours at the level of the inlet against the length of the least conjugate in 447 cases. Diameters of 103 mm., or less, were always associated with abnormal labours; diameters of 137 mm., or more, with normal labours. In the intervening range 104–136 mm. both abnormal and normal labours occurred. The critical level is 114 mm. Only 66 cases (14·7 per cent.) are represented on the flat portions of the graph. However, the abnormal case



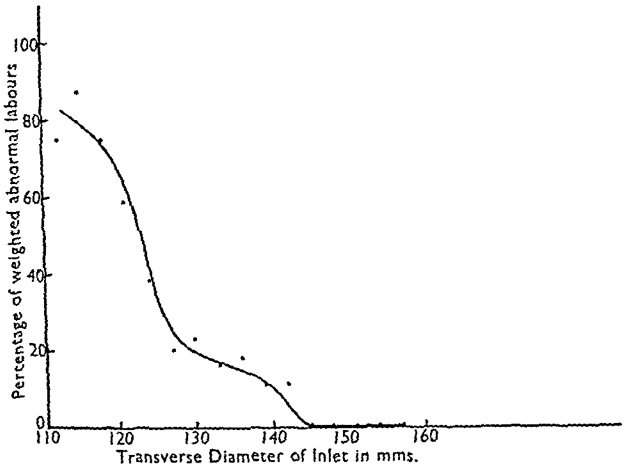
Graph 2.
Graph of least conjugate diameter. Based on 447 cases. Range, 90–155 mm. Mean, 124·8 mm. Critical level, 114 mm. Efficiency, 38·5 per cent.

occurring at the 136-mm. level was one in which the transverse was 131 mm. and the area 140 sq. cm., and in which the practitioner reported that a Cæsarean section had been done for non-engagement of the head after 26 hours' trial labour, the child weighing 8.7½ lb. This report is so astonishing and so little in accord with the general trend of the observations that it may well be regarded as an error of observation. If this case is excluded, all labours of 129 mm. and over were normal and 172 cases (38·5 per cent.) lie on the flat. The range is 90–155 mm. The mean is 124·8 mm., somewhat lower than I reported in 1943, no doubt because the material is not now unselected, but contains potentially

abnormal cases in larger proportion. It may be reiterated that this figure again bears out the findings of Ince and Young, and of Thoms, that the mean value of the obstetrical conjugate quoted in text books is much too low.

Transverse (Graph 3)

Graph 3 is that of the transverse diameter of the brim and has several features which contrast with those of the preceding graph. The range is much less, only 111–158 mm.; this is in conformity with Ince and Young's finding that the transverse diameter is much less liable to variation than the conjugate, the respective cœfficients of variation being 5·4 per cent. and 8·5 per cent. No cases are represented on the top left section of the graph; in fact the smallest diameter noted, 111 mm., was associated with normal labour, the pelvis being an exaggerated long oval type with a brim index of 120.



GRAPH 3.
Graph of transverse diameter of inlet. 438 cases. Range, 111–158 mm. Critical level, 123 mm. Efficiency, 11·8 per cent.

Fifty-two cases of the total of 438 (11·8 per cent.) lie on the bottom right section. The critical level is 123 mm. These observations suggest that the transverse diameter, considered alone, is not of much assistance in prognosis.

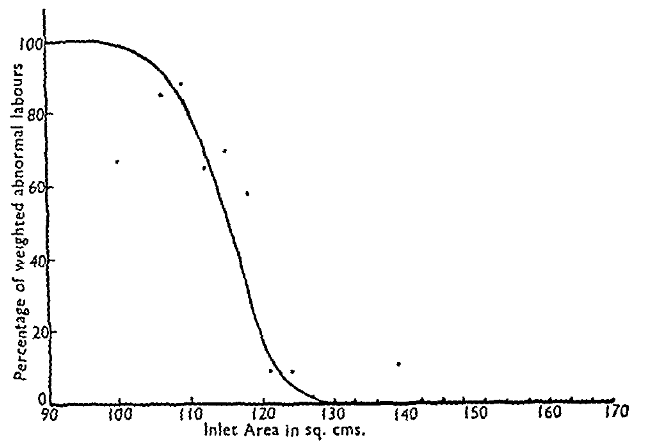
Inlet Area (Graph 4)

This graph is based upon observations in 433 cases. Of these, 104 are represented on the flat of the graph, but this number may justifiably be increased to 236 if the case referred to above (*see* "Conjugate") is neglected. This represents 54·5 per cent. of the total. The mean is 130·2 sq. cm. and the critical level is 115 sq. cm.

Brim Index (Graph 5)

It is impossible to construct a graph comparable to the foregoing for the brim index. The observations are so widely scattered that it is impossible to reduce them to any systematic form. The graph shown indicates the broad trend of the observations only; it shows that most normal labours tend to be grouped round the 90–100 level, above and below which the percentage of abnormal labours increases. The graph can be taken to indicate a relatively higher mechanical efficiency in the round pelvis. Of the 433 observations, only 5 (1·2 per cent.) are on the flat portion of the graph, and the brim index is clearly of no use in prognosis.

In Part II of this paper I suggested that some standard definition of a flat pelvis based upon the brim index should be agreed upon, and that the standard should be set at that level at which flatness *per se* could be considered to have some obstetrical



GRAPH 4.
Graph of inlet area. 433 cases. Range, 91–170 sq. cm. Mean, 130·2 sq. cm. Critical level, 115 sq. cm. Efficiency, 54·5 per cent.

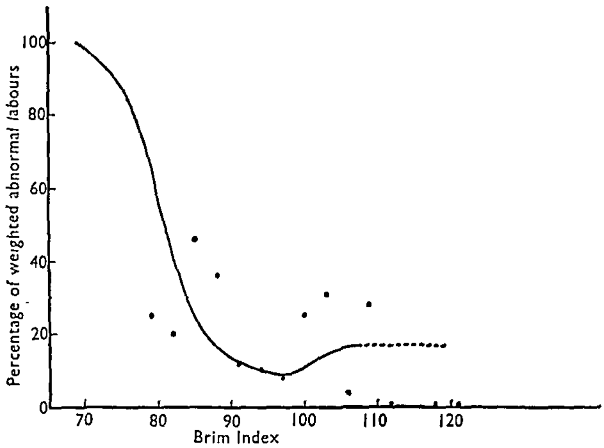
significance. The graph produced does perhaps suggest the solution, for, broadly speaking, indices below 80 were associated with abnormal labours and those above 80 with normal labours. The standard flat pelvis might, therefore, be defined as one with a brim index of 80 or less.

MID-PLANE

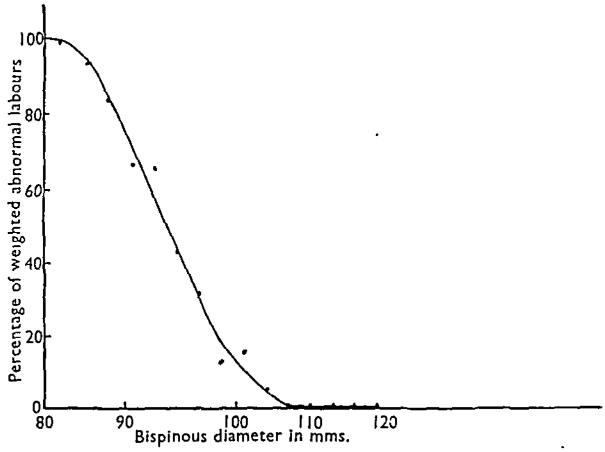
The features of the mid-plane to be considered here are the antero-posterior (or pubo-sacral) diameter, the bispinous diameter, and the transverse diameter (defined in Part I). Since two coronal plane diameters are available, the area may be calculated using either one or the other.

Antero-posterior of Mid-plane (Graph 6)

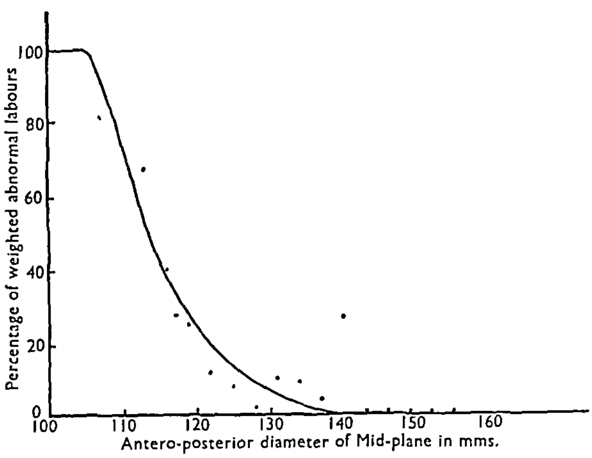
Graph 6 is based upon 439 cases. Of these a mere 27 (6·2 per cent.) are represented on the flat sections of the graph. The range is 100–156 mm. The critical level is 113 mm. It may be noted that the percentage of abnormal cases falls rapidly and regularly from 100 to 128 mm. when it reaches 2 per cent., but that a significant number of cases are abnormal between 128 and 140 mm., giving the slope a rather long tail.



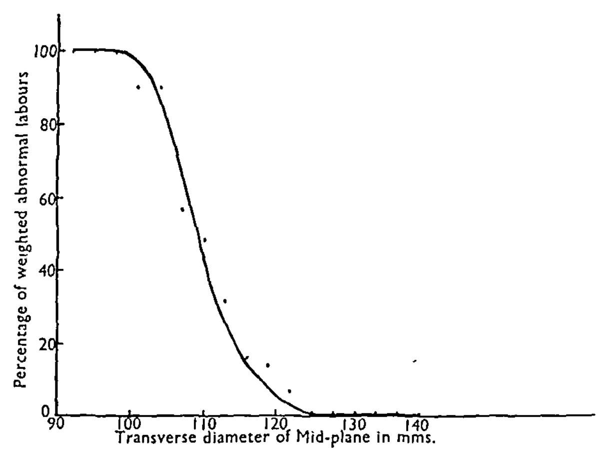
GRAPH 5.
Graph of brim index. 433 cases. Range, 69–120. Critical level 80. Efficiency, 1·2 per cent.



GRAPH 7.
Graph of bispinous diameter. 426 cases. Range, 81–125 mm Critical level, 95 mm. Efficiency, 20·6 per cent.



GRAPH 6.
Graph of antero-posterior diameter of mid-plane. 439 cases. Range, 100–156 mm. Critical level, 113 mm. Efficiency, 6·2 per cent.



GRAPH 8.
Graph of transverse diameter of mid-plane. 420 cases. Range, 91–139 mm. Critical level, 109 mm. Efficiency, 16·4 per cent.

Bispinous

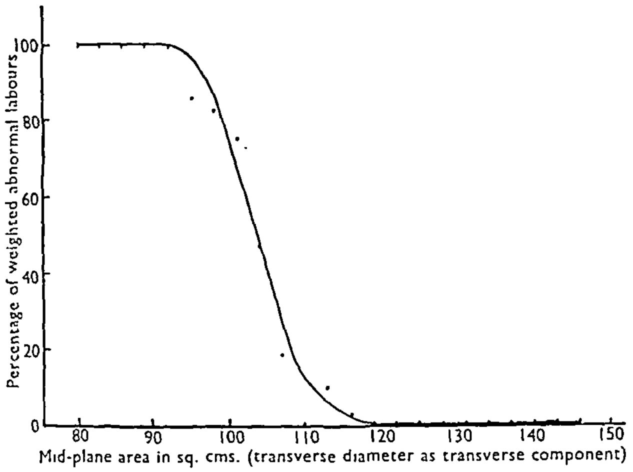
Graph 7 is based upon 426 cases, of which 88 (20·6 per cent.) are on the flat. The range is 81–125 mm. The critical level is 95 mm. There are only three cases on the left-hand flat section. Normal delivery was possible in one case with a bispinous diameter of 85 mm. and in two other cases of 87 mm. This supports my previous contention that the bispinous is not a critical diameter at the mid-plane, and that it is not the available transverse diameter. If it were, one would expect arrest of a 9·5 cm. fœtal head in many more cases than actually occurs.

Transverse (Graph 8)

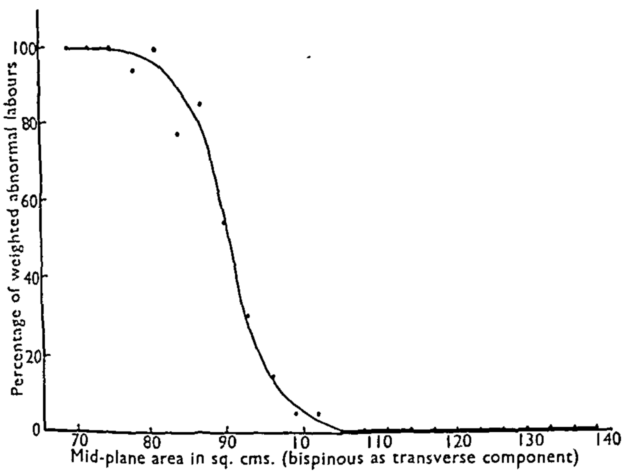
Here there were 69 (16·4 per cent) cases on the flat in a total of 420. The range is 91–139 mm. and the critical level is 109 mm. It may be noted that the general features of this graph are much the same as that of the bispinous: the two diameters tend to vary together though at times they may differ very considerably

Mid-plane Area (Graphs 9 and 10)

Graphs 9 and 10 are based upon observations on 416 cases. The former shows areas calculated with the transverse diameter as the transverse component and the latter areas calculated with the bispinous.



Graph 9.
Graph of mid-plane area (calculated from antero-posterior and transverse diameters). 416 cases. Range, 79–146 sq. cm. Critical level, 104 sq. cm. Efficiency, 49·0 per cent.



Graph 10.
Graph of mid-plane area (calculated from antero-posterior and bispinous diameters). 428 cases. Range, 68–138 sq. cm. Critical level, 90 sq. cm. Efficiency, 43·2 per cent.

Graph 9 has 193 cases (46·4 per cent.) on the flat, but excluding one case at 115 sq. cm., a 7-lb. child which arrested at the mid-plane in a brow presentation and required forceps delivery, the number can be increased slightly to 204 cases (49 per cent.). The range is 79–146 sq. cm. and the critical level 104 sq. cm.

Using the bispinous diameter, 428 cases were available, and of these 185 (43·2 per cent.) were represented on the flat. The range is 68–138 sq. cm. and the critical level 90 sq. cm.

Discussion

If we regard the relative number of cases on the flat sections of the graphs as an index of the efficiency of the diameter in allowing a definite prognosis to be offered, we can compare the values of the various pelvic characteristics by comparing the percentages. It is convenient to summarise the information contained above in tabular form (Table I).

The table makes it clear that the areas at inlet and mid-plane are a better guide to prognosis than any one diameter. The only diameter which approaches the areas in usefulness is the conjugate, and the importance of this diameter at the brim has long been recognised.

It may be noted that Heyns (1945) has criticised at some length the accuracy of some radiological measurements. He claims that Nicholson's method

TABLE I
Relative Efficiency of Selected Pelvic Characteristics in Allowing a Positive Prognosis

Level	Characteristic	Percentage Positive Prognoses Possible
Inlet	Area	54·5
	Least Conjugate	38·5
	Transverse	11·8
	Brim Index	1·2
Mid-plane	Area (using transverse)	49·0
	Area (using bispinous)	43·2
	Bispinous	20·6
	Transverse	16·4
	Antero-posterior	6·2
Outlet	Posterior sagittal	69·7
	Symphysis-biparietal distance	3·0
	Subpubic angle	1·3

of area computation fails to agree with the planimetric area of the brim by an average of 8·5 per cent.; that what is universally measured as the transverse diameter of the brim is in fact a diameter of the cavity of the pelvis, and that measurement of the pubo-sacral diameter is impossible radiologically. It is not possible in this article to discuss these controversial claims, but some mention must be made of the first, which is relevant to this discussion. Considering that the sacral promontory often projects forwards into the inlet and interrupts its regular curve posteriorly, it would be surprising if Nicholson's method did always produce the planimetric area. For practical purposes, Heyns

arguments can be dismissed. Nicholson's method of finding the brim area can be regarded as a mathematical means of correlating two pelvic diameters, and there is ample evidence to show that the brim area so determined is of great help in prognosis. For Heyns' remarks to carry any weight, it would have to be shown that the planimetric area was of *greater* significance than the theoretical area, and that planimetric measurement could be accurately made.

It has been pointed out before that the method of weighting the abnormal cases results in abnormality, as revealed in the graphs including minimal abnormality. The critical levels are therefore the

TABLE II

TABLE OF REPORTED INLET MEASUREMENTS

Author	O.C.	Trans.	Area	Wt. child	Remarks
Thoms	$9\frac{1}{2}$	$11\frac{1}{4}$	84	6·11	
	$10\frac{1}{4}$	$13\frac{1}{4}$	107	7·3	
	$8\frac{1}{2}$	11	74	5·12	
	$10\frac{1}{4}$	$11\frac{1}{4}$	93	6·10	
	$10\frac{1}{4}$	$11\frac{1}{2}$	93	6·13	
	10	12	94	6·9	
	$9\frac{1}{4}$	$12\frac{1}{4}$	89	8·4	
	$10\frac{1}{4}$	$12\frac{1}{4}$	99	7·2	
	$9\frac{1}{2}$	$11\frac{3}{4}$	88	6·5	
	$10\frac{1}{4}$	$10\frac{1}{2}$	85	6·8	
	$11\frac{1}{4}$	12	106	6·14	
	10	12	94	7·10	
	9	13	92	7·2	
	9	$12\frac{3}{4}$	90	9·6	
	10	12	94	8·15	Hard mid-forceps. Should have been section
Nicholson	—	—	85	—	
	—	—	88	—	
Williams	9·8	11·1	85	—	Elective section
Ince and Young . .	8·8	13·1	90	5·12	Section after 68-hr. trial
	9·1	11·7	84	6·4	Section after 55-hr. trial
	10·3	11·3	91	5·15	Section after 20-hr. trial
	11	13·3	115	8·5	Section for maternal exhaustion after 120 hrs.
	10·8	12·3	104	7·2	Failed engagement of breech after 56 hrs.
Allen	9	13	92	—	Elective
	9·7	14	117	—	Four previous neonatal deaths. Elective
	10	13·7	107	—	Section after 4-hr. trial
	10·1	11·9	94	—	Section after incomplete 7-day trial
	10·2	13·7	109	—	Two previous sections
	10·2	12·1	97	—	10 para. No living full-term child
	10·3	13·4	108	8·13	Section after 36 hrs. trial. Head stuck
	10·4	11·2	91	7·1	Elective section
Deliveries per vaginam					
Nicholson	—	—	94	6·7	Normal delivery
Williams	8·5	12·3	82	6·6	Normal in 3 hrs.
	9·7	12·4	94	6·3	Normal in 7 hrs.
	10	12·7	99	5·14	Normal
	10	12·8	100	7·0	Delayed engagement
	9·9	12	85	6·0	Normal in $1\frac{1}{2}$ hrs.
Ince and Young . .	9	13·5	95	5·12	Normal in 112 hrs.
	9·5	13	97	7·12	Normal in 70 hrs.
	9·5	12·3	92	6·0	Normal in 14 hrs.
	9·5	14·2	106	7·8	Normal in 6 hrs.
Allen	10·4	12·3	100	7·0	Normal in 9 hrs.
	10·4	13·6	111	7·0	Normal in 30 hrs.

levels at which there is a 1 : 2 chance of labour being very slightly abnormal. Normal labour may still occur at levels which on the graph show 100 per cent. abnormal labours. The main use of the graph is to allow a fairly definite prognosis to be given as to when a labour will be mechanically *normal.* A point of the greatest interest in cases of pelvic contraction is whether vaginal delivery will be possible: here the graphs are of little assistance. It may be worth while to summarise some recent opinions on the critical levels for vaginal delivery. Selected case reports of my own, and from the literature, are summarised in Tables II and IV.

Nicholson expressed the opinion that vaginal

TABLE III

Inlet Measurements as Diagnostic Criteria

(modified from Weinberg and Scadron)

Group	Antero-Posterior in mm.	Antero-Posterior—Transverse in mm.	Area* in sq. cm.	Prognosis	Expected Outcome
A	over 105	240	106–113	Good	Spontaneous delivery is the rule
B	100–105	220–240	88–113	Fair	Vaginal delivery is usual
C	90–100	200–220	75–88	Guarded	Cæsarean section probable
D	75–90	below 200	below 75	Poor	Cæsarean section necessary

* Area calculated from Nicholson's formula, using various combinations of antero-posterior and transverse to give the appropriate sum.

TABLE IV

Selected Series of Cases with Mid-plane Contraction

Author		Pelvic Dimensions						Wt. child	Remarks
		Antero-Posterior	Bispinous	Transverse	Post Sagittal	Area (using transverse)	Area (using bispinous)		
Allen	1	101	94	104	—	81	74	6·3	Section after 7 days' incomplete trial
	2	102	85	98	—	79	68	5·15	Elective section (on X-ray report)
	3	112	89	96	—	84	78	8·8	Mid-forceps. Marked moulding
	4	106	94	102	30	85	79	9·4	Section after 31 hrs. trial
	5	108	89	100	—	85	75	5·9	Normal in 14 hrs. Small moulded head
	6	108	94	101	—	86	80	—	Elective section. Height, 4 ft. 11 in. G.C. pelvis
	7	106	90	105	—	87	75	5·15	Elective section. Inlet area 104 sq. cm.
	8	108	81	102	—	87	69	6·2	Elective section (on X-ray report)
	9	130	84	99	50	101	86	7·6	Elective section. Toxæmia and X-ray report
	10	111	84	103	—	90	73	7·0	Elective section (on X-ray report)
	11	126	87	108	35	107	89	8·2	Normal in 16 hrs.
	12	122	87	112	33	107	90	7·12	Normal in 15 hrs.
	13	135	86	106	—	113	91	6·12	Easy mid-forceps in 13 hrs.
	14	125	85	91	38	89	84	7·7	Section. "Previous labour proved contracted outlet"
	15	100	106	120	30	94	83	6·4	Normal in 16 hrs.
Williams	16	101	110	—	—	—	87	5·14	Low forceps after 2 hrs. at vulva
	17	102	103	—	—	—	82	6·8	Normal in 13½ hrs.
	18	100	94	—	—	—	74	—	Elective section
	19	107	109	—	—	—	91	—	Mid-forceps for cavity arrest after 4½ hrs.
	20	122	87	—	—	—	83	8·3	Section after 3 days' trial

delivery became uncertain when the brim area was 90 sq. cm. or less. Ince and Young could express no definite opinion owing to their small number of cases: from the table, their five cases delivered by section had a mean area of 96·8 sq. cm., and the four cases delivered vaginally had a mean area of 97·5 sq. cm., an insignificant difference. Of the 15 cases of Cæsarean section reported by Thoms, the mean area was 92 sq. cm. and the mean length of the conjugate 98 cm. It seems clear from the cases in Table II, and from the opinions expressed, that the actual level at which vaginal delivery may become impossible is quite variable. Cæsarean section was required with areas of 115, 109, 108 sq. cm.: in contrast to this, Williams reports rapid vaginal delivery of children of 6·6 and 6 lb. through areas of 82 and 85 sq. cm. respectively.

Some further light on the matter is contained in an article by Weinberg and Scadron, who have analysed 500 cases. As a diagnostic criterion, they use a figure representing the sum of the conjugate and the transverse diameter: they claim an accuracy of 97·8 per cent. accurate prognoses (a claim which must be accepted with some reserve, since the only errors allowed are 11 cases in which vaginal delivery was advised and resulted in still births!). They publish a useful table (Table III), which is shown here modified by the addition of the calculated areas. It will be noted that the areas corresponding to the sums have a range. Thus, a sum of 24 cm. will result from a conjugate of 9 and a transverse of 15, and the area will be 106 sq. cm.: the same sum may represent a conjugate and a transverse each of 12 cm., and the area in this case is 113 sq. cm. This table reinforces the opinion that correlation of two diameters is more useful than the use of one diameter alone. The use of the sum, however, is probably inferior to the area method, since the latter automatically makes an allowance for the greater mechanical efficiency of the round as compared with the oval pelvis.

As regards the mid-plane, much the same remarks apply as in the case of the inlet. It is again seen that computation of the area by either method, *i.e.*, by considering the relation between two diameters, is a better guide than consideration of any one diameter alone. As far as single diameters are concerned, the bispinous has a slight advantage over the transverse, but the mid-plane area calculated with the transverse is better than that calculated with the bispinous. Its efficiency is 49 per cent., approximating that of the inlet area (54·5 per cent.).

The critical levels for vaginal delivery at the midplane are more difficult to define than in the case of the inlet, relatively little attention having been given to the subject. The measurements of fifteen of my own cases and five reported by Williams (1943) are given in Table IV. These may be referred to in the light of opinions offered by various authors.

Both Ince and Young, and Nicholson, investigated the course of labour in relation to the midplane area, calculated using the bispinous as the transverse component. The former authors found that of the cases requiring forceps, 39 per cent. had areas below 85 sq. cm., whereas of the cases delivering spontaneously only 18 per cent. had areas below this level. They found "a definite association . . . between difficulty in labour and reduction in size of the outlet of the pelvis and of the subpubic angle". It seems clear that they consider normal delivery possible at the 85 sq. cm. level. Nicholson thought that "a line between the chances of normal and difficult labour occurs somewhere about 90 sq. cm.", but it does not appear from the context that he means by this to imply that vaginal delivery becomes improbable below this figure. In my own and Williams' cases, vaginal delivery was possible with areas of 75 sq. cm. (Case 5), 78 sq. cm. (Case 3), and 82 sq. cm. (Case 17). Williams and Phillips (1946) state that the prognosis is serious if the antero-posterior is reduced to under 4 in. (101 mm.) and the bispinous to under 3·8 in. (96 mm.). This means an area of 76 sq. cm., and with this estimate I entirely agree.

Weinberg and Scadron (1946) use as a criterion of mid-plane contraction the sum of the bispinous and posterior sagittal diameters, and summarise their conclusions in the statement that delivery vaginally occurs rarely with mid-plane dimensions totalling 13·5 cm., and almost never below 13 cm. This opinion does not agree with my observations, for in the relatively few cases in which the posterior sagittal was measured, there are two (Cases 11 and 12) where normal delivery occurred with totals of 12 and 12·2 cm. Incidentally, these same authors found (not unexpectedly) that Ball's method of volumetric estimation of the mid-pelvis from the bispinous diameter alone was unreliable.

For the reasons outlined in Part I of this paper, I do not think it sound practice to consider either the bispinous diameter itself or sums or areas derived

from it as the main diagnostic criterion at the level of the mid-pelvis. Certainly, this diameter may cause obstetric difficulties, but Cases 3, 5, 11, 12, 14, and even 13 in Table IV show that vaginal delivery of normal heads presumably having minimum diameters of 95 mm. can occur through bispinous diameters of under 90 cm. This would certainly not be expected if the bispinous were actually the limiting coronal plane diameter. Moreover, a theoretical argument suggests that it is not so. If we agree that vaginal delivery becomes uncertain when the brim area reaches 90 sq. cm., why should the area at the midplane have to be reduced to about 75 sq. cm. before delivery becomes impossible? No doubt, moulding becomes maximal in the cavity of the pelvis, but I doubt whether this can account for a reduction of 15 sq. cm. in the area of the presenting fœtal head. I therefore prefer to use the mid-plane area calculated from the transverse diameter rather than from the bispinous.

Of my own cases, two vaginal deliveries took place with areas of 84 and 85 sq. cm. (Cases 3 and 5): all the remaining seven with areas below 90 sq. cm. were abnormal, though it must be admitted that Cæsarean section was sometimes an elective procedure, and such cases might therefore be regarded as "non-assessable". My own experience suggests that the mid-plane area at which vaginal delivery becomes uncertain is about 85 sq. cm., 5 sq. cm. less than the corresponding brim area. The corresponding area calculated from the bispinous would be 10–15 sq. cm. less, *i.e.*, 70–75 sq. cm., which agrees with Williams and Phillips' suggestion.

A summary of the position at the mid-plane is that normal delivery is almost certain if the area is 110 sq. cm. and if the bispinous is 100 mm. Vaginal delivery becomes very doubtful when the area falls to 85 sq. cm. (or 70–75 sq. cm., using the bispinous for calculation).

The criteria on which to base prognosis at the inlet may be summarised by saying that if either the conjugate or the brim area are reduced to 105 or lower, the possibility of Cæsarean section being required arises: when either figure reaches 90, section becomes a decided probability. If the conjugate and brim area are above 130, normal delivery may be predicted with confidence.

At the outlet, it has previously been suggested that the available posterior sagittal be used as a prognostic guide: vaginal delivery becomes uncertain when this is 48 mm. or less: normal labour above 65.

In the course of analysing the cases, several other findings of possible interest were noted, and will be briefly discussed.

Placental Site

Although there is still some difference of opinion as to whether or not the apparent fusiform thickening of the uterine wall often seen on lateral films represents the placenta, the evidence in favour of this interpretation seems now to be reasonably convincing. For instance, McCort, Davidson, and Walton, using the lateral film supplemented by air cystography when no shadow was seen, were able successfully to exclude placenta prævia in 97 per cent. of cases: these authors quote Dippel and Brown as demonstrating the placenta by the lateral film in 90 per cent. of 203 cases, and Buxton, Hunt, and Potter as being successful in 86 per cent. of 106 cases. If the method can be used with such a large measure of success to exclude placenta prævia, it seems a logical deduction that the shadow seen is, in fact, the placenta.

One argument which has been adduced against this interpretation is that the shadow is posterior in O.A. presentations, and *vice versa*, that in effect it lies on the opposite side of the uterus from the fœtal back. If this were so, it might be logical to deduce that the shadow represented merely a collection of amniotic fluid occupying the space between the fœtal limbs. In a random selection of 50 of my own cases, the placenta was opposite the back in 24 cases, and in the remaining 26 cases both placenta and back were either anterior or posterior.

It is generally agreed that the placenta is normally implanted on the fundus, either anterior or posterior. The site of implantation in 505 of my cases was as follows:

Anterior on fundus	185 (36·6 per cent.).
Posterior on fundus	138 (27·3 ,, ,,).
Lateral on fundus	24 (4·8 ,, ,,).
Not seen	158 (31·3 ,, ,,).

The large number of cases in which the placenta was not seen is due mainly to technical factors. During the early cases in the series, no special lateral film for demonstration of the placenta and fœtal limbs was taken: with the special film now being taken, I estimate that the placenta is visible in 85–90 per cent. of cases.

Operative Measures

In Table V is summarised the type and amount of operative intervention. The main point of interest is the number of Cæsarean sections performed. Of the total of 54 such operations, representing 12·6 per cent. of the total number of cases, only 12 can be said to have been done for conditions entirely unrelated to disproportion. There were thus 42 cases (9·8 per cent.) in which the operation was done wholly or partly because of known or suspected disproportion. Considering that the first 220 cases in the series were unselected primiparæ, in the vast majority of whom there was no suspicion clinically of disproportion, the incidence seems disturbingly high. Thoms (1941) quotes an incidence of Cæsarean section of 2·3 per cent. in 1100 primiparæ, and says that "pelvimetry does not tend to increase the amount of obstetric interference". My own experience has unhappily been precisely the reverse: I am all too often in the embarrassing position of learning that a radiological report has been used as the reason for an elective procedure, either induction or section. There has been, in fact, a definite tendency for the clinicians to read into the report much more than has been intended, and this has made me more and more chary of mentioning minor abnormalities. The situation will improve only when the clinicians reach some fuller understanding of the limitations of the method. No doubt, these circumstances are peculiar to local conditions, but it appears to be a possible danger worth mentioning.

TABLE V

DETAILS OF OPERATIVE INTERFERENCE

Total cases	428	
Cæsarean section	54	(12·6%)
Mid-forceps	25	(5·8%)
Low forceps	54	(12·6%)
Episiotomy	39	(9·1%)
Manual rotation	3	(0·7%)
Miscellaneous	3	(0·7%)
Medical induction	51	
Surgical induction	63	
Reasons given by practitioners for induction:		
Radiological report suggesting abnormality	40	
Toxæmia	20	
Post-maturity	18	
Other	3	
No reason stated	18	

The same tendency towards operative interference is seen in the analysis of the reasons given for induction of labour. In 40 of the 99 cases in which induction was attempted, the only reason given was "X-ray report of abnormality". It may, incidentally, be noted that nearly half the attempted medical inductions were unsuccessful in bringing on labour.

Pelvic Type

The following table (Table VI) shows the incidence of pelvic type met with in this series.

The only finding requiring mention is that android features apparently become much more common as the brim index decreases, and this leads to some suspicion that the shortening of the posterior sagittal segment of the conjugate may be as much to do with flatness as with any trend to masculinity. The number of android cases, however, is small, and too much stress cannot be laid on such an interpretation.

In view of Caldwell and Moloy's emphasis upon the importance of the android pelvis, an analysis of labour in relation to android features was undertaken (Table VII).

The percentage of weighted abnormals occurring in the cases without android features may be taken as the basis of comparison. The cases with android features have been analysed to show the incidence of abnormal labours at the level of the inlet and mid-plane. If android features are important *per se* and irrespective of size, the percentage of weighted abnormals should be greater in such pelves than in the control series. The table shows a high percentage of abnormals at both levels in android flat types: but from Graph 5 we have already seen that abnormals are numerous in flat pelves irrespective of the relative length of the posterior segment, and it may be doubted whether the high percentage shown is of significance. The only other figure above that of the control series is the 38·4 per cent. of the android round pelvis at the mid-plane.

This analysis cannot be interpreted dogmatically owing to the small number of cases involved, but the following conclusions may, perhaps, be suggested:

(*a*) Android features are not particularly common in this series.

(*b*) Such features did not appear *per se* to influence the course of labour. (Naturally a *small* pelvis with android features is less efficient than a round pelvis with the same brim area, if only because it diverges from the ideal round form.)

(*c*) Android features become more common as the brim index decreases.

(*d*) In round pelves of small size, android features are likely to lead to difficulty at the mid-plane rather than at the inlet.

SUMMARY

Examination of the course of labour in relation to variations in selected pelvic characteristics suggests that on the basis of pelvic mensuration alone a reasonably accurate

TABLE VI

INCIDENCE OF PELVIC TYPE AND ANDROID FEATURES

Type	Cases	Percentage of total	No. showing android features*	Percentage of type showing android features*
Flat (Brim Index, 80 or less)	22	4·2	8	36·3
Round (Brim Index, 81–99)..	369	70·6	53	14·3
Long oval (Brim Index, 100 or over)	132	25·2	10	8·2
Total ..	523	100·0	71	—

*Here and in Table VII, android features means that the percentage ratio of the posterior sagittal segment of the conjugate to the whole conjugate, measured as described in Part II, is less than 40 per cent.

TABLE VII

INFLUENCE OF ANDROID FEATURES ON THE COURSE OF LABOUR

Type	No. cases	Weighted abnormals at inlet level		Weighted abnormals at midplane level	
		No.	Percentage	No.	Percentage
Full series without cases with android features	381 364	110 —	29·6 —	— 134	— 36·8
Flat pelves with android features	5	5	100·0	3	60·0
Round pelves with android features	39	6	15·3	15	38·4
Long oval pelves with android features	8	0	0	1	12·5

TABLE VIII

GUIDE TO PROGNOSIS BASED UPON MEASUREMENT OF SELECTED PELVIC CHARACTERISTICS

Probable mode of delivery	Conjugate in mm.	Brim Area in sq. cm.	Mid-plane Area in sq. cm.	Bispinous in mm.	Posterior Sagittal of Outlet in mm.
Vaginal delivery certain without any evidence of disproportion	over 130	over 130	over 120	over 110	over 65
Vaginal delivery reasonably certain, but there may be evidence of minor disproportion requiring forceps ..	105–130	105–130	95–120	90–110	50–65
Vaginal delivery uncertain, and if possible will show clear evidence of disproportion	90–105	85–105	80–95	80–90	45–50
Vaginal delivery extremely unlikely. Elective Cæsarean section justified	under 90	under 85	under 80	under 80	under 45

prognosis of the probable mechanical course of labour can be offered in the majority of cases. From my own experience and from a limited review of the pertinent literature, the following table (Table VIII) is offered as a tentative guide to prognosis. The table is based on the assumption that the fœtal head is of fixed standard size, 100 mm. in diameter: if there is evidence that the head is smaller or larger than this assumed normal, the interpretation will require modification accordingly.

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ABSTRACTS

Results of Roentgen Treatment of Leukæmia, Bernard Pierre Widmann, M.D., Philadelphia, Pennsylvania, *Amer. Journ. Roent.*, April 1946, lv, No. 4, 377.

This is a review of 110 cases of chronic myelogenous and lymphoid leukæmia in Philadelphia General Hospital. Forty-six were too advanced for treatment, fifteen were not traced. Of the forty-nine patients treated and followed up, twenty-four had lymphoid and twenty-five myeloid leukæmia.

Duration of life

Twelve patients lived six months or less; seventeen (70 per cent.) lived three years or more; seven lived more than five years (two lived thirteen years, one eighteen and one nineteen years). There was no appreciable difference between myeloid and lymphatic. Symptomatology, age, sex, and race ratio were similar to that observed in the literature.

The blood count, basal metabolic rate and clinical condition determined necessity of treatment. No standard technique was universally satisfactory since some patients were clinically better with a blood count maintained at a level higher than normal.

The principle was to adhere to the smallest dose compatible with reasonable clinical health. 50 r daily or up to weekly or even monthly was sometimes sufficient. Other cases needed 200 r. The quality of ray appeared unimportant.

The nodes were treated as necessary, the main treatment being to spleen, mediastinum, and ribs.

Whole body radiation was not as satisfactory as local treatment.

In three cases the count fell to 2000 but later increased. These three patients lived more than three years. The red cell count had little apparent effect on prognosis, but a marked disproportion between normal hæmoglobin and red blood cells was seen in the terminal stages. I. apT.

Hæmatological and Clinical Characteristics of Leukæmia, Russell L. Haden, M.D., Cleveland Clinic, Ohio, *Amer. Journ. Roent.*, April 1946, lv, No. 4, 387.

Four hundred cases were seen in fourteen years in the Cleveland Clinic:—

Acute myeloid	16·5 per cent.
Chronic myeloid	24·7 „
Acute lymphoid	15·3 „
Chronic lymphoid	29·5 „
Acute and chronic monocytic	14 „

Sixty-one per cent. were men. All ages were affected. Many of the characteristic signs, specially in acute leukæmia, are due to toxæmia. This, by its depressing effect on the bone marrow, is often a factor in the anæmia which is usually present. Of 250 patients studied, only twenty-four had hæmoglobin of 80 per cent. or over. Only three cases of acute leukæmia had normal hæmoglobin. The anæmia is often macrocytic unless there has been severe hæmorrhage.

Acute lymphoid leukæmia occurred chiefly in children. Two-thirds of the patients were under ten years. Bone and joint pain was an outstanding symptom. Many cases were aleukæmic. Symptoms were as described in text books—pallor, energy loss, enlarged spleen, palpable glands, though not necessarily very large.

Acute myeloid or myeloblastic leukæmia occurred at any age. Symptoms were very varied but joint involvement less marked. Anæmia and fever were the chief features. The white cell count was not usually very high. Two thirds of the group (fifty patients) had a total white count below 10,000. Three cases showed myeloblasts in the marrow and not in blood.

Chronic lymphoid leukæmia is often mild. Eighty-eight per cent. of the patients were over fifty years; only three were under forty-five. The leucocyte count was usually high, with a high proportion of lymphocytes and often no blasts. Many patients had no anæmia. Infection as a complication was rare.

Chronic myeloid leukæmia. Weakness was chief symptom, due partly to anæmia, partly to toxæmia. The spleen was often very large and hæmorrhage was more common than in lymphoid. Most patients were middle-aged and had a high leucocyte count. Blasts were usually present.

Monocytic leukæmia. The clinical picture was varied. The leucocyte count was seldom high—60 per cent. never had a count above 10,000. Sometimes there were no blasts. The spleen and glands were seldom enlarged; mouth infections were common. The youngest patient was three and a half months, but half of this group were over forty-five years old.

I. apT.

ABSTRACT

Treatment of carcinoma of the bladder, G. Schmidt, (Wuerzburg), *Strahlentherapie*, 1943, lxxiii.

The treatment of the primary carcinoma of the bladder has always been one of the most ungrateful and difficult problems of urology. Up to the present time the opinions as to the best therapeutic procedure differ considerably.

I. Electrocoagulation (E.C.)

1. E.C. has been found of value by the majority of urologists in the treatment of benign papilloma of the bladder.
2. Transurethral E.C. has been found of certain value in cases of pedunculated papillomatous carcinoma.
3. E.C. is contra-indicated in infiltrating bladder carcinoma, as the incompletely coagulated tumour tends to spread more rapidly.
4. Transvesical E.C. is by many considered as unsuitable on account of the danger of dissemination and recurrence.

II. Operative methods

1. Excision of a papillomatous tumour is considered as insufficient; its main dangers are recurrence and cellulitis of the bladder wall.
2. Wide resection of a favourably situated tumour with well marked edges is often very successful.
3. Total extirpation of the bladder in case of infiltrating carcinoma at the base of bladder and trigonum has in the past almost always been rejected. Lately, however, the opinion is becoming more frequent that, with improving operative technique, especially with ureter transplantation, more satisfactory results may be expected from total extirpation in the future.

III. Radiotherapy

1. Radiotherapy alone in primary carcinoma of the bladder has very few adherents in Germany. The majority of German urologists are against X-ray and Radium therapy. In contrast to this are the often surprisingly good results reported mainly from America, where this form of treatment of carcinoma of the bladder is very popular.
2. In deep X-ray therapy of malignant tumours of the bladder the protracted-fractionated method of Coutard is being almost exclusively used. The best reported curative results are about 35 per cent. Although in the majority of cases this method does not give 5-year cures, it often gives worth-while palliative results, also in inoperable cases, and makes distressing clinical symptoms such as frequency and hæmaturia disappear a short time after irradiation.
3. A majority of urologists is opposed to radium-therapy as the only method of treatment, on account of the difficult technique and the painful irritation of the bladder frequently following treatment. Only few urologists have obtained good results with radium therapy. The best results were obtained by Darget with 43 per cent and Barringer with 24·1 per cent 5-year cures. The most suitable cases for radium treatment are those tumours situated at the base of the bladder and in the region of the trigonum. As a rule open implantation of the tumour by means of radium needles is carried out: a few urologists prefer in small tumours transurethral radium implantation. Radium beam therapy is mostly impossible on account of the insufficient amounts of radium at the disposal of most Radium Institutes.
4. Combined X-ray and radium therapy of the cancer of the bladder is the least used of all methods. It is almost universally rejected. Difficulties in dosage or technique are probably responsible for the rejection of this in other carcinomata rather successful method.
5. Contact X-ray therapy, which has steadily gained ground during the last years, has been successfully used in carcinoma of the bladder. The dose is still far from established and varies between 5000 and 25,000 r.

IV. Combined operation and radiotherapy

The combination of operative and radiotherapeutic methods has been reserved in the first instance for the treatment of the not radically operable carcinoma of the bladder. The results thus obtained are comparatively favourable, if one considers the particularly bad prognosis of this type of tumours. However, the number of reports regarding combined treatment of tumours of the bladder is rather small, and large statistics of the results are not yet available. Postoperative radium-therapy, in conjunction with operation, constitutes an important and promising therapeutic method.

* * *

The following principles can be established for the treatment of the primary carcinoma of the bladder:—

1. Operative treatment is always indicated when the tumour is completely removable. In such cases resection of the bladder wall is preferable to excision of the tumour.
2. Electrocoagulation should not be used at all in carcinoma of the bladder, except in combination with preoperative X-ray therapy and only in papillomatous tumours.
3. All operated carcinoma should have post-operative radiotherapy, whether a complete removal of the tumour was possible or not.
4. Radiotherapy alone is indicated in infiltrating, inoperable carcinoma.
5. Excellent palliative results can be obtained with deep X-ray therapy in the distressing symptoms of incurable cases.
6. Radium treatment is an important method especially in conjunction with X-ray therapy. As

radium when applied intravesically often produces severe cystitis, the intravaginal application of radium is recommended for carcinoma of the bladder in women in suitable cases. Contact X-ray therapy will possibly become a serious competitor to radium in the near future.

7. Neither operation nor radiotherapy alone is the method of choice but both methods have their indications. The individual method of treatment, either operation with post-operative radiotherapy or radiotherapy alone according to the findings and prognosis, has to be considered as the most promising method of treatment of carcinoma of the bladder at present. By closer co-operation between urologists and radiotherapists better results should be obtained in the treatment of the carcinoma of the bladder than have been obtained so far.

H.C.S.

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LIST OF PUBLICATIONS RECEIVED

The Hon. Editors wish to acknowledge the receipt of the following:—

Abstracts of World Medicine, March 1947.

Abstracts of World Surgery Obstetrics and Gynæcology, March 1947.

Acta Radiologica, February 1947.

American Journal of Orthodontics, February 1947.

Archives of Physical Medicine, February and March 1947.

Ars Medici, February 1947.

Australian and New Zealand Journal of Surgery, October 1946.

Bulletin der Schweizerischen Akademie der Medizinischen wissenschaften, March 1947.

British Medical Journal, March 15, 22, 29, April 5.

Electrical Engineering Abstracts, February 1947.

Hispalis Medica, January 1947.

Indian Journal of Radiology, February 1947.

Journal of the Franklin Institute, February 1947.

Journal of the Institution of Electrical Engineers, Part I, March 1947.

Journal of the Royal Egyptian Medical Association January 1947.

Journal of Thoracic Surgery, February 1947.

Lancet, March 15, 22, 29, April 5.

Medicina Clinica, January 1947.

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New Zealand Medical Journal, December 1946.

New Orleans Medical and Surgical Journal, February 1947.

North Carolina Medical Journal, February 1947.

Photographic Journal (A), March 1947.

Physics Abstracts, February 1947.

Physical Review, February and March 1947.

Post-Graduate Medical Journal, March and April 1947.

Proceedings of the Royal Society of Medicine, February 1947.

Public Health Reports, February 1947.

Quarterly Review of Dermatology and Syphilology, December 1946.

Radiology, February 1947.

La Radiologia Medica, February 1947.

ıp the deficiency at longer wavelengths; at 0·25 Å the absorption is approximately equal to that for water and beyond this greatly exceeds it. Fig. 9 compares the measured transmission through the pressdwood "D" and water, and shows the

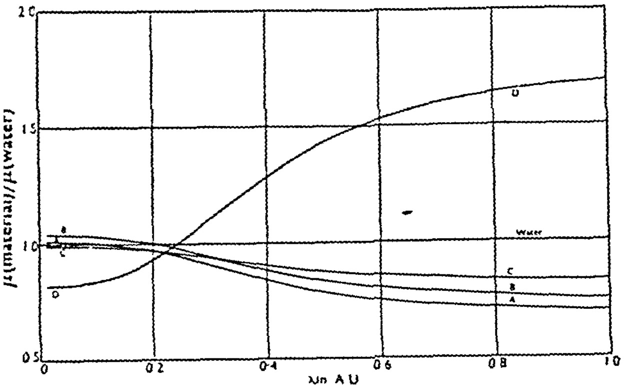

Fig. 8.

divergence from water, in opposite senses, for γ rays and for long wavelength X rays. At the intermediate wavelength 0·23 Å the transmission in the pressdwood is nearly the same as in water, but exact coincidence with the water curve would appear to be at a somewhat shorter wavelength than is indicated in the calculated curve in Fig. 8.

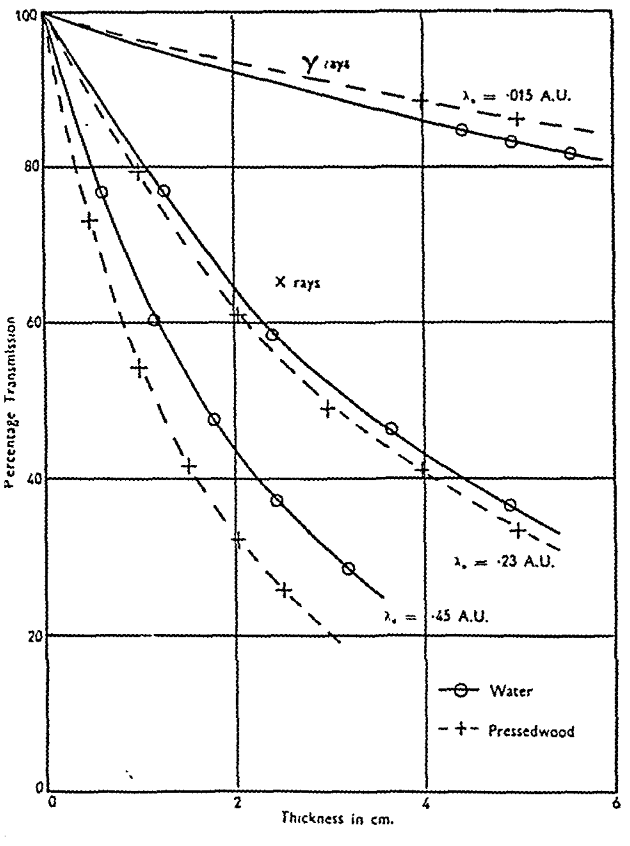

Fig. 9.

Conclusion

Both the experiments and theoretical considerations reported above show that care is necessary in selecting a material for the purpose of depth dose measurements. In spite of the difficulties of using a liquid, water appears to be the most satisfactory medium; its atomic and electronic properties are almost exactly the same as those for tissue of average composition, and it is available in a chemically pure state having a standard density. Much less can be claimed for the other materials investigated. Rice may be deficient in electron density as well as in effective atomic number; some pressdwoods may agree reasonably well with water up to wavelengths of about 0·2 Å, since in this region a little excess electron density may compensate for the lower atomic numbers of most woods. Both pressdwoods and waxes, however, appear unsafe for use at wavelengths greater than 0·2 Å, particularly in the low voltage therapy region. In view of the complex nature of absorption and scatter phenomena in an extended medium, a quantitative and exact correlation between depth dose measurements in different media cannot be made. It seems essential, therefore, that close agreement of electronic and average atomic properties with some standard such as water should be sought before using any material for the purpose of an extended investigation.

Similar experimental methods to those described are being applied to the determination of electronic density and effective atomic number of various types of tissue, bone and biologically related substances. By using more homogeneous X rays a greater accuracy in the determination of effective atomic number is aimed at, and it is hoped that the data so obtained will help in a closer study of true energy absorption in various media.

Acknowledgments

I am greatly indebted to Professor W. V. Mayneord both for the experimental facilities he put at my disposal for testing the powder mixtures and also for his continued and helpful interest in the whole investigation. My thanks are also due to Mr. L. F. Lamerton for his assistance with part of the experimental work, and to Dr. C. W. Wilson, Mr. W. J. Meredith, and Mr. N. Robinson, who kindly supplied me with samples of pressdwood.

Summary

The suitability of various materials, commonly used for depth dose measurement, has been tested by comparing their electron densities and effective atomic numbers with those of water. A powder mixture has been prescribed and tested which is satisfactory as a filling medium for "bolus" bags and for depth dose work in hollow anatomical models. Experimental methods for determining both the electron density and effective atomic number of light substances have been developed and have enabled similar critical tests to be applied to substances of indefinite composition such as mixed waxes and pressdwoods.

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AGENESIS OF THE LUNG

Report of a Case

By V. O. B. GARTSIDE, M.A.(Cantab.), M.R.C.S.(Eng.)
From the Department of Thoracic Surgery, The General Infirmary at Leeds

GORDON T., aged 7 years, was first sent to hospital at the age of 5 years, because his mother noticed a "swelling in the neck." An X ray showed bilateral cervical ribs, for which no treatment was advised. In 1941 he was examined by the School Medical Officer, who diagnosed "pleural effusion," and the child was referred to the Thoracic Surgical Department for investigation.

The mother said that he had never had a serious illness, but "easily got cold on his chest." He played games with other children without becoming breathless and had not suffered from a chronic cough. There was no recent history of chest illness. On examination, the child was found to be well developed physically and of normal intelligence. In the left supraclavicular triangle there was an irregular swelling the size of a walnut. On palpation it was found to be continued upwards and backwards as a firm rod of tissue, and a similar rod of tissue could be felt on the other side of the neck. These were cervical ribs. The scapulæ were equal in size, but the superior angle of the right was elevated one and a half inches above the level of the left, and this was thought at first to be due to shortening of the levator angulæ scapulæ muscle, as described by Sprengle. From the appearance of the X rays it seems more likely that it is secondary to the deformity of the cervical spine. The left side of the chest was markedly flattened and movement was poor. On percussion the note was very much impaired, but not uniformly, and it had not "the feel of fluid." The air entry on the right side of the chest was normal. On the left, breath sounds could be heard over a narrow strip to the left of and parallel to the sternum and over a small area in the 5th, 6th and 7th spaces. There was a diffuse pulsation in the region of the 3rd and 4th ribs to the left of the sternum and maximal just above the nipple. The apex beat was external to the nipple line in the 4th space. There was a systolic thrill with a loud, harsh, systolic murmur at the base,

FIG. 1.

and a reduplicated second sound at the apex. There were no other physical signs and there was no limitation of movement, or pain on movement, of any part of the spine. At this stage, the nature of the chest lesion was not suspected.

RADIOLOGICAL EXAMINATION (Fig. 1)

The right lung field was clear. The left field was opaque, particularly in the middle zone. The trachea and heart were displaced to the left, but the diaphragm occupied a normal position. The lateral view suggested some aeration at the left base. There was a considerable amount of aerated lung tissue between the heart and the sternum. The heart was grossly rotated as well as displaced, but its exact definition was difficult.

BRONCHOGRAM (Fig. 2)

The left main bronchus was seen to be only about half its normal length. It tapered fairly abruptly to end in a small bronchus, giving rise to many slender twigs. This bronchus supplied a wedge-shaped segment of normal lung tissue lying immediately above the dome of the diaphragm in the costo-vertebral gutter. The fine bronchi within the small area appeared normal. In spite of the patient being kept on his left side the lipiodol flowed over and filled the right bronchial tree. The bronchial tree of the right lung appeared normal, except that rotation had taken place in such a way that the middle lobe bronchus came off medially and passed to the left hemithorax. From a consideration of the bronchogram it was possible to make a diagnosis of "agenesis of the left lung."

FIG. 2.

CERVICAL SPINE (Fig. 3)

The X-ray picture was difficult to interpret because of the multiple anomalies. The 4th cervical vertebra was wedge-shaped, as also was the 1st thoracic. The 6th and 7th had bifid spines and a cervical rib was present on each side. (N.B.—There are some anomalies in the vertebræ D_6–D_{10} and ribs 9 and 10 on the left side appear to be fused near their posterior ends (Fig. 1).

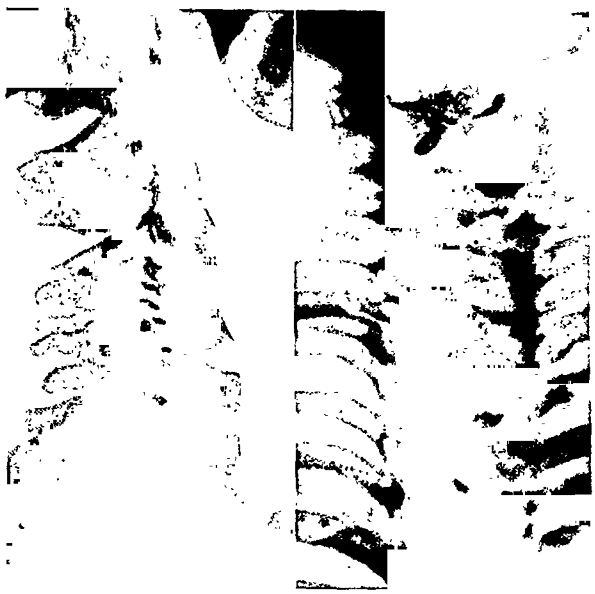

FIG. 3.

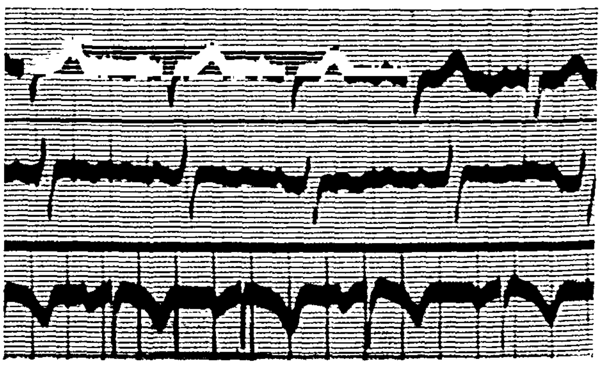

FIG. 4.

ELECTROCARDIOGRAM (Fig. 4)

The electrocardiogram had a most unusual appearance in that lead 3 was similar to lead 1 viewed upside down. This could have been due to the leads being crossed, but two more records gave the same appearance. This made the interpretation so complicated that it is published without comment.

DISCUSSION

In 1937, Hurwitz and Stephens gave a detailed account of 34 cases of agenesis of the lung. They described a case of their own and reviewed the

literature from the point of view of symptomatology and diagnosis. Jamuni and Ellis reported a case in 1938. So did Killingsworth and Hibbs in 1939. The condition is scarcely mentioned in the text-books and Birnbaum and Blacker say only, "congenital hypoplasia and maldevelopment of some of the lobes of the lung, or of the whole lung, is very rare; and the children affected generally die of asphyxia at birth as a result of these conditions. If they survive, the opposite lung undergoes compensatory hypertrophy and undertakes the function of the undeveloped lung." Of the cases described in the literature, three were stillbirths, six died in less than a week, thirteen in less than six months, one in five years and fourteen lived varying periods from five to seventy-two years. Of thirty-three cases in which the sex was stated, nineteen were males. Absence of the left lung occurred in twenty-three out of thirty-seven cases which I have been able to trace up to 1939. Only two were diagnosed before death, but in one or two cases, death was precipitated by bronchoscopic examination. Lipiodol examination has been performed in Germany, but I cannot find any record of a bronchogram which showed the condition seen in Fig. 2. In their review, Hurwitz and Stephens mention that in the case which they reported, stertorous breathing was the outstanding clinical feature, whilst dyspnœa and cyanosis have been observed by some people. As regards physical signs, they mention flattening of the affected side, scoliosis, displacement of the apical impulse, flatness of percussion note and absence of breath sounds on the affected side. The breath sounds and percussion note are commonly affected by the hypertrophy of the functioning lung, and it is obviously impossible to diagnose the condition from the physical signs. X ray shows massive opacity on the affected side with displacement of the trachea and mediastinum to this side. The diaphragm is not elevated to any great extent and this rules out the diagnosis of massive collapse which might otherwise be made. Post-mortem examinations in cases of agenesis have shown two separate types of condition. In the first, the bronchus ends in a blind sac with no suggestion of lung tissue on that side. In the second, there is a rudiment of lung tissue which may or may not have been aerated during life. The pleura may be present or absent. The space which the lung would occupy if normal, is taken up by the hypertrophied lung on the other side, displaced mediastinal structures and either fluid, adipose tissue or persistent thymus. Hurwitz and Stephens complete their discussion by pointing out the occurrence of associated abnormalities. They list anal stricture, absence of the diaphragm, œsophago-tracheal fistula, accessory thymus and hypoplasia of the face. Œsophago-tracheal fistula is one of the more common developmental abnormalities in the chest, and, unless a very early operation is undertaken, the condition is not compatible with life. Food passes into the lungs and causes a rapidly fatal pneumonia. Dr. Lissimore supplied me with the details of a case which he had had in which agenesis of the lung was associated with œsophago-tracheal fistula. In the case which I am reporting the associated abnormalities were spina bifida, wedge-shaped vertebræ, cervical ribs, fusion of ribs, congenital high scapula and a congenital heart lesion, probably a septal defect.

The origin of agenesis of the lung has been attributed to a variety of causes. At one time it was thought to be a secondary defect consequent upon such a primary condition as enlargement and displacement of the thymus. This may be the explanation in some cases, but when there occurs a variety of associated developmental errors, some of which are outside the thorax, as in this case, it would seem more likely that there has been a primary developmental error in the germ-plasm.

Acknowledgment

I have pleasure in acknowledging the help received from Dr. A. S. Johnstone and the staff of the Department of Diagnostic Radiology, General Infirmary, Leeds.

Summary

1. A case of "Agenesis of the Lung" in a healthy child is described.

2. The condition is not recognisable as a result of ordinary clinical examination and is dependent on radiographs and a bronchogram.

3. The main features, clinical and pathological, of "Agenesis of the Lung" are described. The occurrence of associated abnormalities is a common feature of the condition, and the case described provides an excellent example of this.

4. It is suggested that "agenesis" is a primary condition due to an error of development in the germ-plasm.

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MEETING OF MEDICAL MEMBERS

Members are invited to show radiographs of interesting cases, preferably on lantern slides.

Members showing cases are requested to hand to the Chairman of the meeting a list of the cases and the member's name for the purpose of record.

THE INTRA-ORAL RADIUM TREATMENT OF CANCER OF THE MOUTH

By John R. Nuttall, M.D., F.F.R.*
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Part II. TECHNIQUE

Moulds

Dental moulds may either be elaborate appliances made up in vulcanite, or more simple devices modelled in dental impression compound. Either is satisfactory so long as it fulfils certain essentials. It must fit accurately and cover the whole lesion, be comfortable in wear, hold the radium securely at the focus-mucosa distance at which the dose was calculated, be easily removed and re-inserted, and only fit comfortably with the radium in correct relationship with the lesion.

Both materials are useful. Vulcanite is light, takes a good finish, and does not distort at body heat. Dental compound is comparatively cheap and is easily worked.

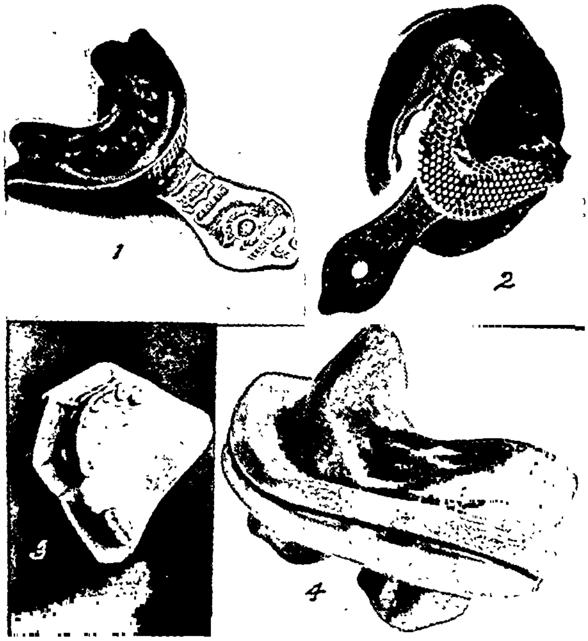

Diagram 1.
The manufacture of a dental mould. (1) Impression-compound impression. (2 and 3) Plaster cast of this. (4) Dental compound mould from plaster cast.

Neither has radiotherapeutic value over the other. In the Manchester Radium Institute both types of materials have been used, but the greater ease of handling dental composition has led to its superseding vulcanite except on very rare occasions. The technique of making moulds has been comprehensively described by Walker,[1] and by MacVicar and Paterson,[2] and Max Cutler prepared a film illustrating dental mould construction in considerable detail.

Intra-oral radium moulds of dental compound can readily be constructed in any Radium Centre, however small, by an interested person, though until proficiency in the handling of the various materials is attained the guidance of a dentist, or dental mechanic, may be very helpful. Briefly there are three stages in the construction of a mould. Firstly, an impression of the lesion and surrounding parts must be taken in a dental impression compound such as Elasto-Velvex. Then a Calspar (plaster of Paris) cast is made from the impression. Finally the applicator itself is moulded *on the plaster cast and prepared to hold the radium* containers. Black tray compound and Attenbury's base-plate are excellent materials for this purpose.

Opinions differ as to the need for shielding off with lead the parts of the mouth which are not to be treated. This is a particularly vexed question when treating the palate, for the tongue may readily receive sufficient radiation to cause a marked reaction. Unfortunately it is almost impossible to incorporate sufficient lead to make an effective shield. The increased weight of the mould with its consequent liability to slip out of position probably outweighs any advantages the lead screen may possess. If lead is not used the mould should be thickened in such a way as to push the tongue as far from the radium as possible without discomfort.

In planning treatments by means of dental moulds, it is necessary to make allowance for the fact that continuous irradiation is impracticable. The mould must be removed while the patient takes his meals, and to enable the nurse to cleanse the mouth. The mould must not be worn during sleep, and it is of psychological advantage to leave some free period for conversation during the daytime. It has been found convenient to arrange that the dental mould is in the mouth only for about eight hours a day, although the total dose is given in an overall time of seven to ten days.

Dental moulds may be used either as the sole means of treatment, or as part of a combined treatment, the other part of the combination being an external mould or implantation of seeds or needles. The choice of method depends upon the site and thickness of the lesion. In many parts of the mouth the affected mucosa lies upon bone which small lesions frequently do not invade. For their treatment, lethal dose to about $\frac{1}{2}$ cm. deep is required, and below this, in the bone, rapid falling off in dosage is an advantage. The single-plane mould with a small radium mucosa distance of $\frac{1}{2}$ cm. fulfils these conditions and consequently has a wide field of usefulness in the mouth. Obviously at so short a distance it is very important that the radium should be placed upon the mould accurately in accordance with the rules for the distribution of foci to obtain homogeneous dosage over the treated area. As the falling off in dosage at the periphery is very rapid, the treated area must be wide enough to leave a good margin round the lesion. A surface dose of 9–10,000 r in seven days can be taken with safety, and, moreover, is necessary if the lesion has any appreciable thickness, for at $\frac{1}{2}$ cm. depth it will have fallen to about 5000 r.

Of the combined methods, the sandwich mould, developed by Fulton in the Manchester Radium Institute, is probably the most satisfactory. Special care is needed in the use of sandwich techniques. The radium planes must be parallel. Dosage must be calculated at successive planes between the moulds, as well as on the skin and mucosal surfaces. As much greater volume is irradiated than when a single plane is used, mucosal dosage may not be so high. A simple chart is given showing the layout for a number of usual lesion sizes.

**Being the subject matter of a thesis accepted by the Fellowship Board of the Faculty of Radiology.*

CHART OF SANDWICH MOULD DOSAGE

	Mg.-h for Tissue 3·5 cm. thick
Inner mould 10 cm.^{2} at 0·5 cm.	1760
Outer mould 18·8 cm.^{2} (oval 6 × 4 cm.) at 2·0 cm.	6250
Inner mould 15 cm.^{2} at 0·5 cm.	2090
Outer mould 24·7 cm.^{2} (oval 7 × 4·5 cm.) at 2·0 cm.	6940
Inner mould 20 cm.^{2} at 0·5 cm.	2720
Outer mould 31·4 cm.^{2} (oval 8 × 5 cm.) at 2·0 cm.	7600
Inner mould 25 cm.^{2} at 0·5 cm.	3170
Outer mould 37·6 cm.^{2} (oval 8 × 6 cm.) at 2·0 cm.	8260

For radium filtered by 1·0 mm. Pt multiply the above figures by 1·1.

For radium filtered by 1·5 mm. Pt, multiply the above figures by 1·22.

Dosage: Mucous membrane 9000 r, skin 6000 r with a dose of about 5000 r at 1 mm. deep to the mucous membrane, as stated in "The Double Radium Mould Treatment of Carcinoma of the Floor of the Mouth and Lower Alveolus," by A. G. G. Melville.

Sandwich moulds are used in the treatment of lesions of the floor of mouth, of the cheek and of the lower lip. The latter is strictly outside the scope of this work, but is mentioned because from it was developed the technique

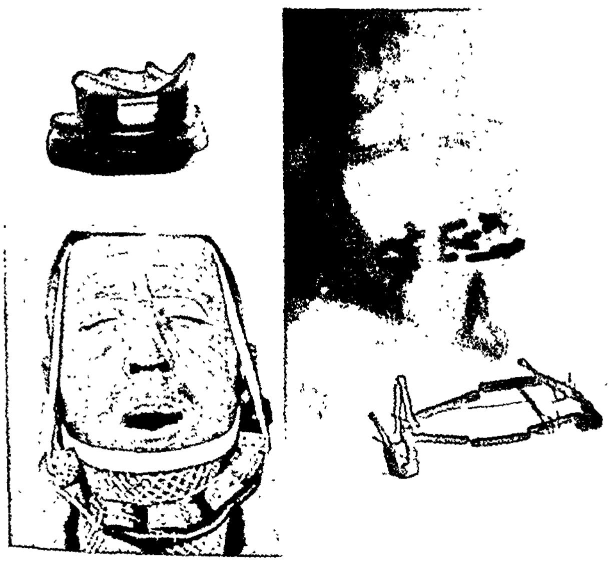

DIAGRAM 2.

Sandwich mould for cancer of floor of mouth. (1) The dental mould. (2) The skin mould. (3) Radiograph showing moulds in position.

for cheek lesions in the neighbourhood of the angle of the mouth. Both parts of these moulds are made of dental compound with the needles buried in it. Usually black tray compound with base-plate outside is used. The radium mucosa distance of the intra-buccal plane is ½ cm. whilst the radium skin distance of the outer part is 1 cm. The buccal mould has a "bite" with a projection through the lips to which the outer plane is attached. A locating device ensures that the two planes always have the same relationship with each other, and a wing-nut provides ready removal.

The sandwich technique employed for lesions of the floor of the mouth comprises two separate moulds worn at the same time. An ordinary dental mould with radium mucosa distance of ½ cm. is used in the mouth. On the skin surface a nidrose mould on which the radium is carried at about

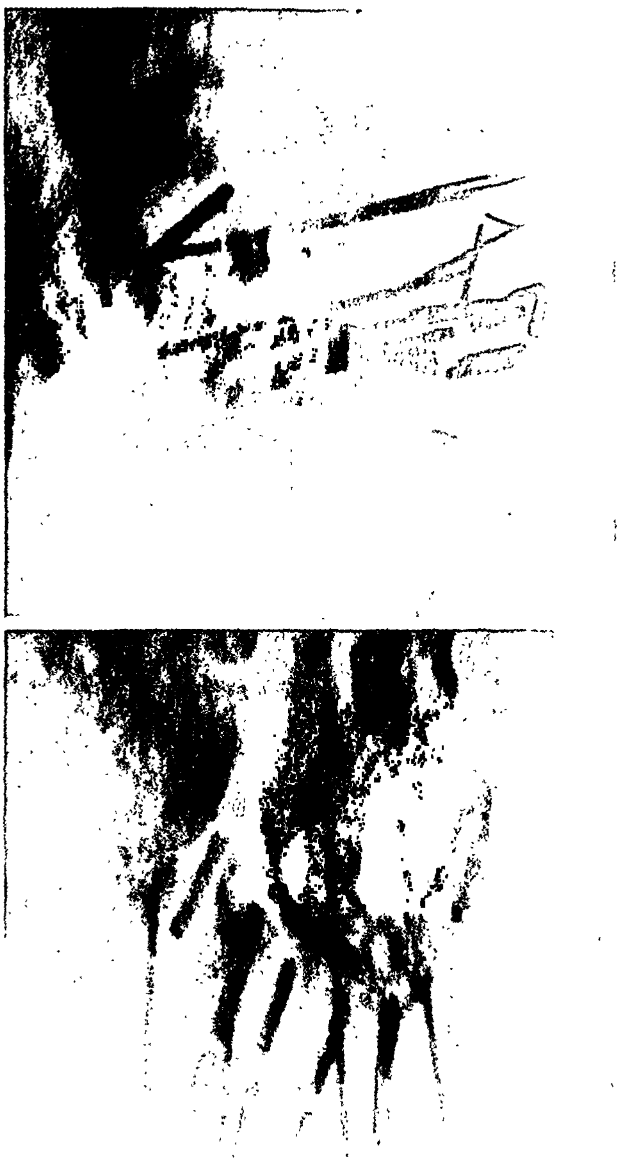

DIAGRAM 3.

Sandwich technique for cancer of the hard palate. Antral needles and palate mould.

2 cm. distance in a ring of rubber tubing is employed. The moulds are worn together for about eight hours a day for an overall period of seven to eight days.

It is usual to aim at a dose distribution which gives about 8000 r on the mucosa and about 6000 r on the skin when using the sandwich principle. The mucosal dose is thus considerably lower than that for a single mould technique.

Occasionally a sandwich technique is used in treating thick palatal lesions. In this the tumour dosage from a palatal mould is increased by inserting a plane of radium needles (3 mg., 4·5 cm. active length, 0·5 platinum) across the floors of the antra and nose.

When floor of mouth lesions invade the under surface

of the tongue, it may be found necessary to build up the dosage delivered from a dental mould by a single plane needle or seed implantation across the tongue. X-ray checking with the mould *in situ* is needed. This is not always a true sandwich procedure, because the mould plane may not be parallel with the interstitial plane. When this occurs tolerance dose is given at the mucosa with a mould, the interstitial radium merely extending the field of radiation.

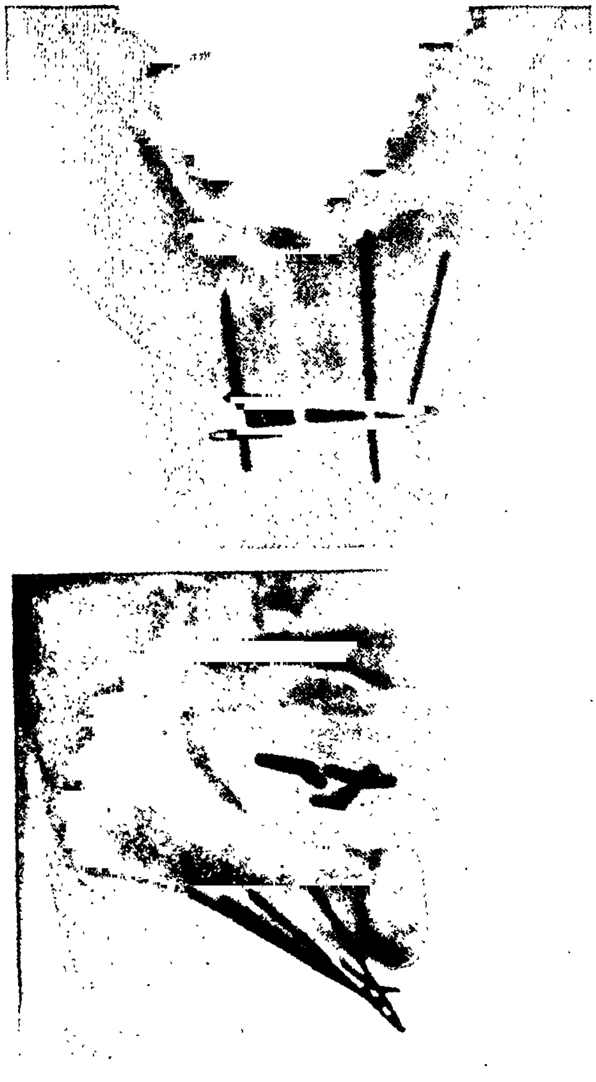

DIAGRAM 4.
Sandwich technique for floor of mouth. Submental needles and dental mould.

The checking of mould treatments is important if dosage is to be accurate. When high doses are given this importance is increased. The earlier checks are made in the mould room whilst manufacture is in progress. Accuracy of the radium-mucosa distance is checked by external caliper measurements of the radium grooves. Micrometer accuracy is only needed for moulds used in research work, but quite small errors in distance produce appreciable errors in dosage. At the distances involved, the dose falls off inversely as the distance, thus a ½ mm. error makes a 10 per cent. error in dose from a mould calculated at ½ cm. focus-mucosa distance. When the radium has been mounted on the mould, the output of radiation from the mould may be measured with an ionisation chamber. Corrections in dosage may be made by altering the overall time. Mistakes in the distribution of radium on the mould may be discovered in this way, and be rectified before the mould is put into use.

As dental moulds are not worn continuously, it is advisable that some check on their insertion and removal should be maintained in the wards. A simple form on which the times of insertion and removal, and the period for which the mould is worn, are entered in columns has been found to be satisfactory. A final column gives the total number of hours up to date.

The use of *intermittent moulds*, of which mouth moulds form a large proportion, necessitates the provision in the ward of a place for their storage when not in the patient, which is secure against loss, and has sufficient screening to prevent danger to the staff. It is undesirable to keep them in the patient's locker, even though the quantity of radium on the moulds is usually comparatively small.

They should be cleaned on removal, and may be kept in some weak antiseptic solution, which must be washed off before re-insertion. When dental compound moulds are used, washing with hot water must be avoided, as this composition readily softens and distorts when the temperature is raised much above that of the body.

IMPLANTATION OF RADIUM

A. The importance of good anæsthesia

The treatment of intra-oral growths by radium implantation is greatly facilitated by a good general anæsthetic, which reduces the risk of death from bronchopneumonia. A poor anæsthetic renders accurate implantation difficult.

Endotracheal anæsthesia is the most suitable type, the tube being passed through the nose in order to leave the mouth available for the therapist. By the use of a basal anæsthetic, it is usually possible for an expert anæsthetist to maintain adequate anæsthesia with endotracheal nitrous oxide and oxygen, a point of particular importance in the treatment of old or ailing patients.

During the immediate post-treatment period special care is required if bronchopneumonia is to be avoided. Some sedative is required on the evening of operation. Morphia gr. ⅙th appears to be adequate, without producing cyanosis after basal anæsthesia. For the first three or four hours after treatment, the inhalation of CO_2 and oxygen for ten minutes each hour is found to be of value in the prevention of lung complications.

When inhalation anæsthesia is contra-indicated, short treatments, such as the implantation of a few radon seeds may be carried out satisfactorily under Sodium Evipan anæsthesia. Unfortunately good relaxation cannot be relied upon and, despite its obvious advantages, the method is not so good as endotracheal anæsthesia for ordinary routine work.

Occasionally even Evipan is contra-indicated and recourse has to be made to a combination of pre-medication and local, or regional, anæsthesia.

In the Manchester Radium Institute, the provision of a good endotracheal anæsthetic is considered of such paramount importance in the intra-oral treatment of cancer of the mouth that provision is made for it in the legal agreements governing the provision of radium treatment services to outside authorities, and treatment is postponed when a suitable anæsthetic cannot be obtained.

B. Technique of implantation

(i) *General.* The insertion of radium needles into the tissues of the mouth with any accuracy calls for a certain degree of skill which, being in large measure mechanical, can only be acquired by practice.

A number of points about intra-oral interstitial radiation are of general importance. If an implantation treatment

goes badly wrong, a second anæsthetic will be needed to rectify the error, and probably the patient will not be a good subject so soon after his first operation. The needles should be so fastened that they will not come out during the treatment period, as loss of even one or two needles seriously affects dosage distribution. A usual method of ensuring this is to make a knot in the radium needle silk just above the eye, and through the loop thus formed, to carry a catgut suture (No. 2 chromicised gut). When the needle has been inserted, this catgut is used to stitch the needle into position, a small, round bodied, fully curved needle being inserted down the path of the radium needle and brought out again about 5 mm. away. Any pull exerted by the catgut thus tends to pull the needle deeper in, rather than to allow it to work its way out. With this method of stitching, anæsthesia for the removal of the needles is unnecessary.

If X-ray examination shows that the implantation is unsatisfactory, it is usually possible either to modify the overall time of treatment or to resort to differential extraction of the needles. If the overall time is reduced to any great extent it will, of course, be necessary to reduce the total dose—a dual process which frequently degenerates into a vicious cycle.

The throat should be packed during mouth implantations with gauze wrung out in saline.

Radium needle silks may become foul during the period that the needles are in the mouth, and cause soreness and ulceration of the angle of the mouth. This may partly be prevented by threading the silks through a piece of soft rubber tubing passed through the lips like a cigar. The silks may either be fixed to the cheek with zinc-oxide strapping, or be stitched together in a bunch.

Biopsies from intra-oral lesions can readily be taken with Noake's turbinectomy forceps if no special biopsy instruments are available. The biopsy should be taken at the beginning of the treatment, when the field is already obscured by hæmorrhage, but in clean cases it is of advantage to delay it until the "key points" in the implantation have been inserted. It is a small point, but when it is desired to have a biopsy of all lesions treated, one that is helpful.

The use of different coloured silks for different strengths of radium needles is useful in mouth treatments, because of the difficulty of seeing the exact position of the individual needles in so small a cavity. It becomes particularly helpful when differential extraction of the needles is contemplated, for the nurse can be told to remove, say, "all the red silked needles from the cheek," an order which is simple to convey and to understand.

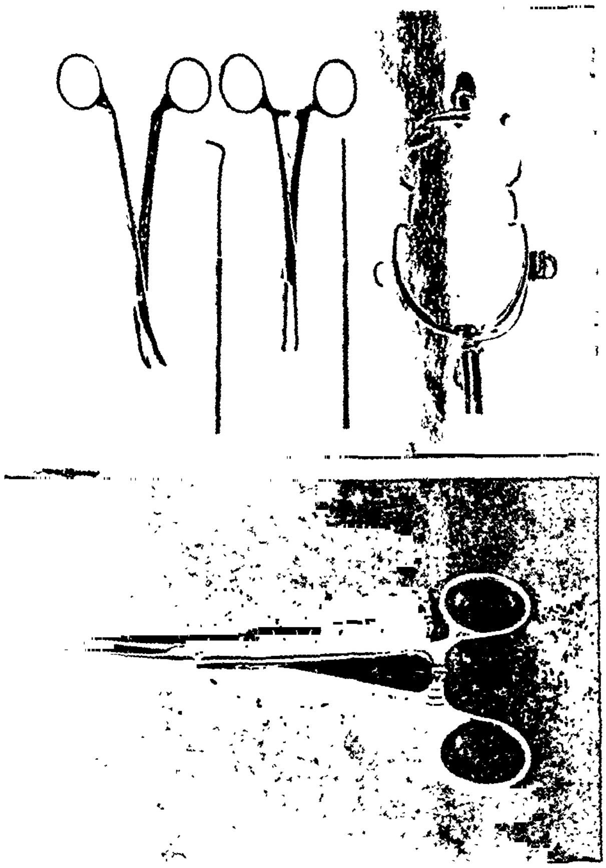

Diagram 5.

Instruments for intra-oral radium implantation. Upper group: Biopsy forceps, introducing forceps, pushers, and Dann's wire gag. Lower: Morrison's forceps for extracting radium needles.

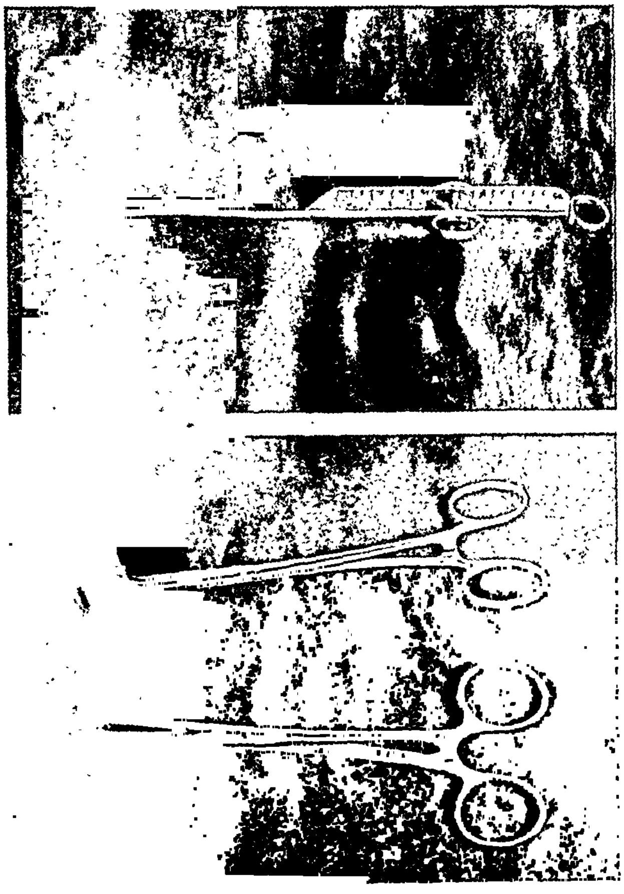

Diagram 6.

Instruments for intra-oral radium implantations. Upper: Herd's measuring device. Lower: Herd's combined *needle-introducers and pushers.*

The following instruments used in radium needle insertion are particularly valuable. It is difficult to obtain good visibility. Two things are necessary—a wide open mouth and a good light. Dann's wire gag gives the former and does not, in itself, cause much obstruction. It must be removed before the silks are fastened to the skin. The Boyle Davis gag is useful for palate treatments but it hinders tongue implantations. The lighting may be intra-oral

John R. Nuttall

(Cameron light) head lamps (or mirrors) and "shadowless" theatre lamp. The latter is most convenient.

Radium needles are inserted with radium introducers, which either hold the needle in the long axis of the instrument, or at right-angles to it. A slender rod of the same diameter as the needle, and with one end hollow-ground may be used to push the needles into the tissues.

The type of needle introducer designed by Herd which is tapered to act as a pusher saves changing instruments, and is easy and quick to use.

It is necessary to measure the size of the lesion for record purposes, and that of the implantation for calculation. A 15 cm. steel rule to be held in the mouth, or Herd's flexible

Diagram 7.
Single-plane implantation of tongue margin.

measuring device, whereby the length is read off on a scale outside the mouth, should be sterilised with the other instruments.

Except in the case of lesions of the dorsum, most implants of tongue are planned as vertical. It is surprisingly difficult to insert in the tongue a vertical plane of parallel needles. To see the insertion of the posterior needles, the tongue is pulled forward. When it falls back into its natural position, X ray shows that the posterior needles are pointing downwards and forwards, and that the needle points are more or less bunched together. Obviously this is undesirable, as it produces a "high spot" of dosage deep in the muscle, which may give rise to necrosis later. By applying the minimum of traction to the tongue and inserting the posterior needles in a slightly backward direction it is possible, in large measure, to overcome this difficulty.

Hæmorrhage from the needle holes persisting after implantation is comparatively rare, although fifteen (or more) needles may be inserted. The stitches which hold the needles in place appear to assist the hæmostasis, to which the plugging effect of the actual needle so largely contributes. A dab of Whitehead's varnish usually suffices to control any needle holes which are found to be oozing at the end of the implantation.

When a large number of needles is inserted, particularly in the posterior part of the tongue, it is advisable to take small bites in stitching them in, for strangulation of tissue causes the tongue to become congested, œdematous and swollen within a few hours. Such a tongue is painfully tense, immobile, dusky in colour and feels to fill the mouth, and complete relief may only be obtained by removal of the needles.

A further small point about the stitching in of posterior needles when there is much hæmorrhage is the need for especial care not to include any of the throat packing gauze in the sutures. This is easy to do, and as it is usually discovered only when the implant is complete, is often very difficult to rectify without cutting the needle silks.

(ii) *Details of different techniques.* (a) *The single-plane implantation.*—The simplest type of radium needle implantation used in the mouth is the "single-plane implantation." In this the area to be treated—about a centimetre clear of known lesion in every direction—is outlined with radium needles of normal linear intensity in some rectangular form. The centre is then put in with parallel lines of needles of half the normal linear intensity about 1 cm. apart, in accordance with the Paterson-Parker dosage system. The dose to be given is calculated at 0·5 cm. from the plane. Thus a block of tissue the size of the plane and 1 cm. thick is irradiated to a selected dosage. Outside this "slab" the dose falls off rapidly.

Unless the plane has a very large area, it is wise to give a higher dose when a single-plane implantation is used than would be the case were a bigger volume being treated by a multi-plane or volume technique. The effective range of this type of implantation is small, and it is not always possible to be sure of the exact extent of a lesion. As a rough working rule, it is both safe and wise to give doses of the order of 7000 r in seven to ten days from medium-sized planes, and 7500 r from small planes. A medium-sized volume implantation should only be given doses in the region of 6000–6500 r in a similar period. Single-plane implantations of larger areas—for example, of the whole cheek—only tolerate smaller doses in the neighbourhood of 6000–6500 r.

Lesions of the oral surface of the cheek may readily be treated by single-plane implantations if a mould is considered unsatisfactory. In this site it is much easier to insert the needles through the skin surface than to attempt to coax them round the corners in the mouth. Because of the curvature of the cheek, it is more satisfactory to insert the main sheet of needles vertically than horizontally. The crossing of the ends can be done with a number of short needles following the curve as a series of short straight sections at an angle to each other. Usually the cheek is implanted because the lesion is spreading up into the alveol-labial sulcus making a mould unsuitable. The 3 mg. needles of 4·5 cm. active length may be pushed upwards from the skin surface, a finger in the mouth steadying the needle, and whilst preventing penetration of the mucosa, assuring that the plane lies just deep to it. The upper end of this plane lies under the zygoma. Occasionally parotitis follows perforation of the parotid duct.

Horizontal single-plane implantations of the tongue are used for superficial lesions of the dorsum. They must be carried out with especial care to ensure that the needles lie immediately below the mucosa. The needles are usually inserted in the antero-posterior direction, so as to follow the lateral curvature of the tongue, short needles being used to cross the ends of the plane. The size of needle used obviously depends upon the size of the lesion to be treated, but the antero-posterior curvature of the tongue limits the length of the needles nearly as strictly as does the lateral curvature. It is seldom possible to do a satisfactory implantation with needles of more than 3 cm. total length and if a longer plane is necessary, they should be used in tandem. Exceptional care in stitching-in the needles is necessary, as they are very prone to come out before their time when placed in the muscular tongue in this manner. Small lesions may be given 7000 r in seven to ten days, but if the whole

dorsum is treated, the dose should be reduced to 6000–6500 r. In checking up this implantation by X rays, the occipito-submental position is found to be most useful.

Radon seed implantations in the mouth are usually of the single-plane variety, although a special one of the palate will be described later. Radon seeds are particularly useful in the treatment of small lesions in the aged, or very frail, as they may be inserted under local or regional anæsthesia, or under Evipan Sodium. All radon seed implantations should be X rayed immediately on completion, as the seeds do not always leave the introducer in the manner intended by the operator, and gaps in the geometrical arrangement necessary for uniform radiation may require filling in by the insertion of additional seeds. In view of radiographic magnification, a marker of known dimensions should be used when the X ray is taken to facilitate measurement of the treated area on the film. For very small areas—of about 2 cm. diameter—a dose of 7000–7500 r may be given. For larger areas, this should be reduced to about 6500 r. As once seeds are inserted, reduction in dosage is almost impossible, careful pre-calculation and area measurement are essential when using them.

The plaque-like lesion of the curved overhanging margin of the tongue presents a problem for the radiotherapist. If it does not exceed 2 cm. diameter, and is superficial, a single-plane radon-seed implantation may afford adequate treatment. Larger lesions, however, require needle implantation. If there is little underlying induration a single-plane technique will be found satisfactory. The needles must be inserted directly under the mucosa, the lesion being almost "threaded" on to them. If this is not done with great care the radium-lesion distance will be found to be too great when the tongue falls back into its normal position. The needles may either be inserted horizontally or vertically according to the actual site of the lesion.

(b) *The multi-plane implantation.*—Intra-oral radium implantations in two planes are often needed when larger volumes of tissue need to be treated, the lesion being sandwiched between the planes. The two planes of radium should be approximately 2 cm. apart in order to avoid over-dosage in the planes and under-dosage between them, because dosage throughout the treated block cannot be uniform. It is, therefore, necessary to consider both the maximum and minimum dose when planning treatments. These should be of the order of 6500 and 5000 r respectively.

The needles in the tongue of two-plane implantations are almost invariably inserted vertically. In this direction the tongue will accommodate needles of about 3 cm. active length or 4 cm. total length. It is, however, almost impossible to cross the lower end of such a plane through the mouth; X rays of attempts to do it through the submental skin are usually most disappointing. Fortunately this rarely matters, because the lesion is situated in the upper part of the plane and a lower end crossing is unnecessary. Allowance must be made for the reduction in effective size of the plane when calculating the dosage.

The posterior two-plane implantation is often needed because lesions involving the anterior faucial pillar, soft palate at its upper end and tongue at its lower end are of frequent occurrence. For the treatment of this lesion, R. G. Hutchison[4] devised the "tongue-pterygoid implantation."

The ideal case is that in which the growth occupies the region of the anterior pillar, spreading perhaps on to the tongue about its junction with the pillar.

The method is simple in practice, but rather difficult to present anatomically.

Three 3 mg. needles of 4·5 cm. active length, and 6 cm. total length, are introduced through the mucosa of the cheek, and are passed backwards through the pterygoid region lateral to the pterygomandibular raphe, and medial to the ramus of the mandible. A fourth, lowest, 3 mg. needle is usually found to deviate outwards and pass outside the jaw. The anterior ends may be crossed vertically in the cheek with 2 mg. needle of 3 cm. active length, and 4·5 cm. total length. This constitutes the pterygoid plane.

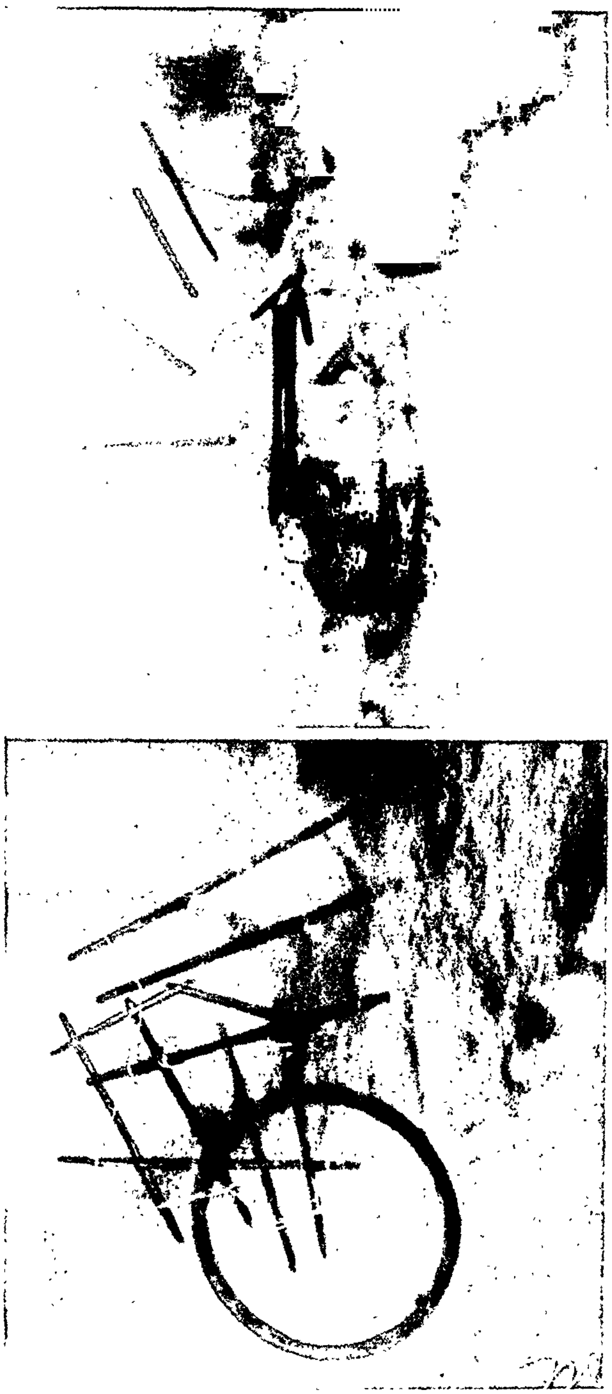

DIAGRAM 8.
The tongue-pterygoid implantation. (The ring is to aid measurement of the X rays of the implantation for calculation.)

The tongue plane consists of four 2 mg. needles which enter the dorsum as far back as possible, and pass down vertically, or preferably with some lateral inclination. They are about 1½ cm. apart, and are crossed by a single 1·33 mg. needle of 2 cm. active length, and 3·5 cm. total length, in the soft palate. With the mouth closed, the tongue may be regarded as being in contact with the palate.

The second lowest needle might conceivably damage the external carotid artery, but the internal maxillary artery and the muscular veins are the only structures in any imminent danger. The internal carotid artery lies medial to the plane and is protected to some extent by the styloid process.

The dosage lay-out is as follows:—

The planes here are 2·5 cm. apart.

Plane A—pterygoid		*Plane B—tongue*	
Area	= 4·5 × 4 = 18 sq. cm.	Area	= 4 × 3 = 12 sq. cm.
Ra	= 4–3 mg. 1–2 mg. = 14 mg.	Ra	= 4–2 mg. 1–1·33 mg. = 9·3 mg.
Filt	= 0·5 pt.	Filt	= 0·5 pt.
Time	= 150 hrs.	Time	= 150 hrs.
Mg.-hrs.	= 2100	Mg.-hrs.	= 1395

Unity represents 1000 *r—intervals are* $\frac{1}{2}$ *cm.*

A.

6·0	*6·0*	*3·4*	*2·4*	*1·8*	*1·4*	. . . A.
1·1	1·4	2·0	2·8	5·4	5·4	. . . B.
7·1	7·4	5·4	5·2	7·2	6·8	. . . A. plus B.

The implantation may be modified somewhat to obtain rather more physically accurately planned planes. To this end, the pterygoid plane may consist of 2 × 3 mg. needles and 3 × 1·5 mg. needles of the same length. The tongue plane may be made up of 2 × 2 mg. needles and 3 × 1 mg. needles of the same length, the needles being placed 1 cm. apart. The plane may be "crossed" in the tongue or in the palate. The author prefers the former, using two 1·33 mg. needles in tandem to obtain the necessary 4 cm. active length with flexibility. Probably the most satisfactory arrangement is a combination of the two methods, the pterygoid plane according to the plan of Hutchison, and the tongue plane as modified with half-intensity needles. It is difficult to insert the larger number of needles into the limited space of the pterygoid plane without crowding.

If there is wide tumour spread towards the mid-line of the tongue the two planes may be widely separated to about 4 cm. with an "open plane" half-way between the main planes. It may be calculated on either a three-plane basis or as a "volume" implantation, although the distribution of the radium will not be entirely accurate for the latter. The volume of reaction is large, but careful pre-calculation and post-operative checking prevent failure due to under-dosage, or radio-necrosis, and can obtain cure.

Occasionally the "tongue-pterygoid" lesion spreads widely on to the soft palate and uvula. The insertion of additional short needles in the soft palate, and one down the uvula is often difficult on account of the friability of the tissues. Radon seeds may with advantage be used in the palate. It is generally found that a circle of 4·5 cm. diameter covers the whole lesion. The outer part of this circle is made up of the usual "pterygoid" needles of the "tongue-pterygoid" technique. Seeds are arranged in the soft palate, uvula, and base of tongue, as two concentric circles with a "centre spot." The latter is usually just to the affected side of the base of the uvula. If the growth extends forwards along the tongue margin, the tongue plane may be continued forwards as a normal tongue-pterygoid implant. Calculation of dosage is more complicated, but it will be found satisfactory to work out the needle implant along the usual lines and then put in the palatal seeds arranged to give a lethal dose to the seeded area. The posterior crossing needle should not be put in the tongue under these circumstances.

"Sandwich" techniques may take the form of a plane in a mould and an implanted plane. An example of this is the use of a transverse plane of needles vertically in the tongue behind a dental mould for the treatment of lesions of the frenum invading the under surface of the tongue. Occasionally it is found practicable to treat lesions of the hard palate which involve bone, but do not involve the antrum or the nose, by means of a palatal mould, and a plane of needles above the palate. For this purpose, 3 mg. needles (active length 4·5 cm.) are inserted through the skin along the floor

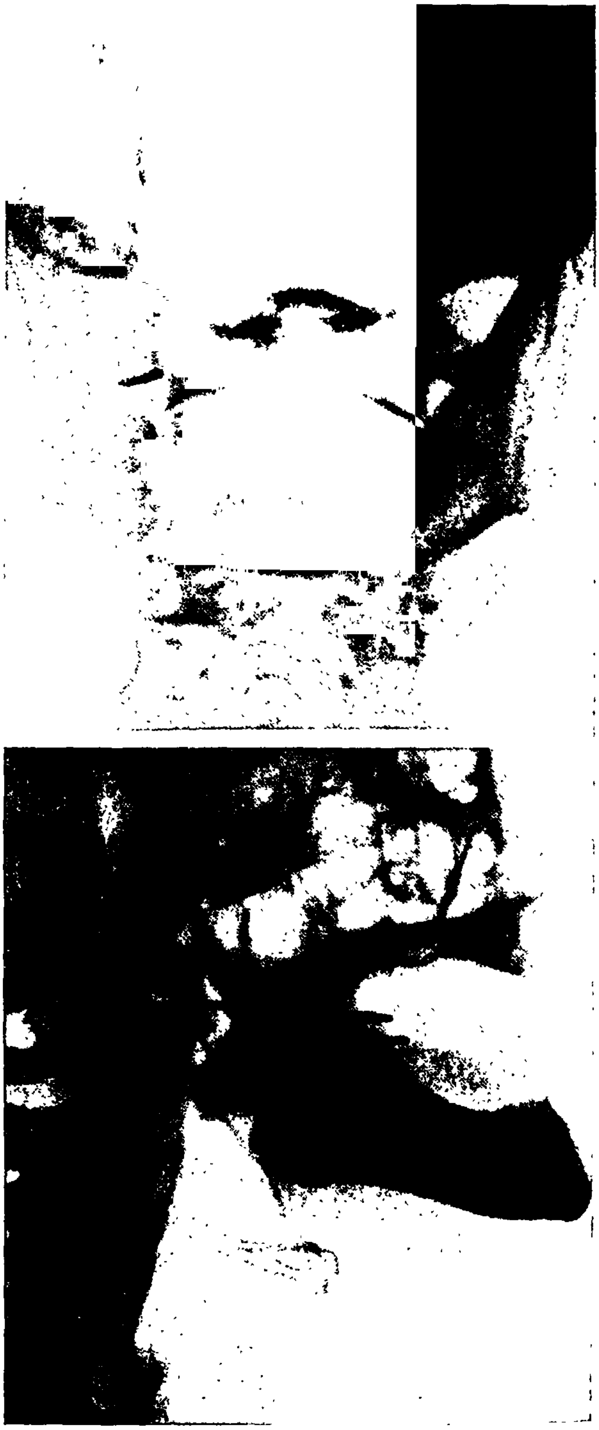

DIAGRAM 9.
Trans-pterygoid needles and palatal radon-seeds.

of the nose, and through the anterior wall of the antra along the antral floor. Careful X-ray checking is needed after this technique has been employed, and this should be done with the mould in position.

(c) *The volume implantation.*—The volume implantation is a further advance of the multi-plane technique. In it the

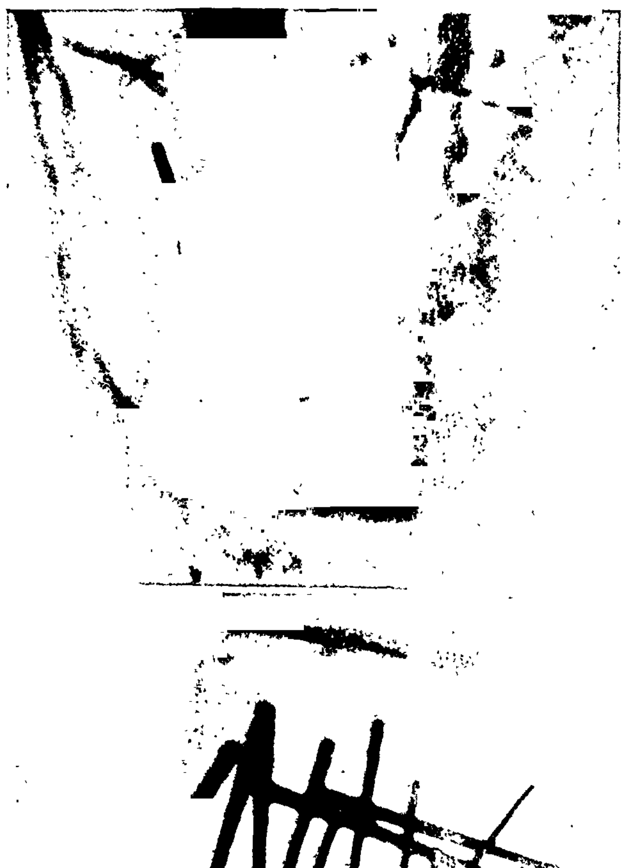

DIAGRAM 10.
Volume-implantation of tongue.

needles are inserted in such a way as to give a reasonably homogeneous dose throughout the volume of tissue being treated. It is a method which requires to be used with care, partly on account of the danger of raising large volumes to high dosage and partly because of the trauma resulting from the insertion of the large number of sources necessary if the implant is to conform to the physicist's distribution. Compromise between the number of sources and the physical rules may make it possible to keep the overall time within the seven to ten day limits, using the radium containers which are suitable for ordinary planar implants.

According to the Paterson-Parker dosage system, the radium is divided into eight equal parts, four of which are put around the rind, two in the core, and one at each end. A minimum of six needles is required to make the periphery of a cylinder, and the more needles used in the core, the more nearly the implant approximates the physicist's ideal. It will, then, be appreciated that if the total quantity of radium is not to be such that the overall time is too short for safety, "half-intensity" needles must be used for the comparatively small volume treated in the mouth.

Doses should not exceed 6500–7000 r in small volumes, 6000–6500 r in medium volumes and 5500–6000 r in larger ones. Very large volumes probably should not be implanted as it is not practicable to give them a tumour lethal dose without grave risk of radio-necrosis.

The technique is applicable to lesions of the floor of the mouth which extend too deeply into the tongue for mould treatment, deeply extending tumours of the dorsum of the tongue, and of the lingual margin and floor of mouth which invade the tongue deeply.

When implanting the tongue and floor of mouth, it is often found expedient to stitch the tongue to the floor of the mouth, or to the lower lip, depending on the extent of alveolar involvement. The periphery of the volume may be entirely in the tongue, or rarely may be completed anteriorly in the lower lip, if alveolar extension renders it necessary.

The same factors govern the layout of the needles in the marginal volume implantation. It should be noted that the placing of needles outside the alveolus is usually unsatisfactory as it results in a wide gap in the core needles, and readily causes necrosis of the bone.

For lesions of the dorsum of the tongue which are excavating rather than fungating, a type of volume implantation which has been described as a "penny-piece" volume is found useful. In this the layout of a volume implantation is followed, but it is carried out with short needles, so that the diameter of the treated volume greatly exceeds its depth. This limitation of irradiated tissue makes high doses possible without serious risk. The technique is curative of lesions which a single-plane implantation just fails to reach completely.

C. The removal of radium needles

Contrary to expectation the removal of radium needles from the mouth after a seven to ten days' treatment is usually simple and does not require anæsthesia, though administration of hyoscine and morphine is helpful. The catgut sutures are found to be sufficiently softened to break on the slightest pressure, and it is rarely necessary to cut them. Local tissue necrosis in the immediate vicinity of the needles renders them freely mobile, and a gentle pull on the silks suffices to extract them almost painlessly. Serious hæmorrhage during extraction of needles is very rare.

Breaking of the silks must be avoided if a needle presents difficulties. Once the silk comes away from the needle, the end is most difficult to find, particularly if the needle is one of the long ones, passing from the cheek into the pterygoid fossa in the "tongue-pterygoid" implantation. Should a needle stick, Morrison's forceps (Diagram 5) may be introduced along the silk, and be tightened over the eye end of the needle. When the path of a needle is occluded by plastic adhesions which hinder its removal, separation of the two sides of the silk is helpful in breaking down the adhesions.

Particular gentleness is required in removing needles from the soft palate, which readily tears and bleeds profusely.

Occasionally, when a patient is very ill, the question of premature extraction of his needles arises. No hard and fast rule is possible; and each case must be dealt with on its own merits. It must be borne in mind that reinsertion of the needles will probably never be possible on account of his general condition and thus, if he recovers from the present trouble, he is doomed to die of his malignancy. Removal rarely appears to save life and may actually increase the difficulties.

John R. Nuttall

THE NURSING-CARE OF RADIUM PATIENTS

The nursing care of patients undergoing radium treatment for cancer of the mouth is of paramount importance.

Three separate periods have to be considered. These are the period of preparation for treatment, the duration of the actual treatment, and the reaction period.

In the main, pre-treatment nursing has to be directed simply towards cleansing the mouth, and doing all that can be done as prophylaxis against post-operative death from bronchopneumonia. The mouth is cleansed with swabbing, frequent mouth-washes, and spraying with the dental

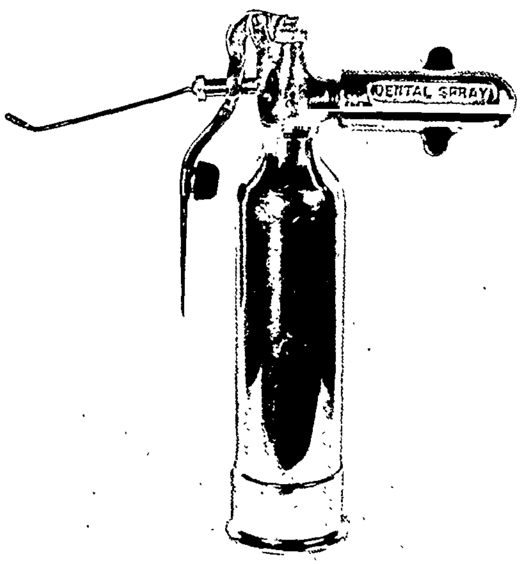

DIAGRAM 11.
The dental hygienator.

hygienator. Many mouth-washes are available, those used in the Manchester Radium Institute being sodium bicarbonate, hydrogen peroxide, and glycerine and thymol. Dentacoid is used in the hygienator. Used with care as regards the pressure of the stream, this instrument will rapidly clean up a dirty mouth almost painlessly.

From the time of admission, patients should be given an expectorant mixture. It is advisable to get them accustomed to taking oxygen through a nasal catheter, so that this trying process will not need to be learnt with a sore post-treatment mouth, and so that the taking of oxygen may become dissociated in their minds from critical illness.

The nurse, or doctor, should explain those things about the treatment which will require his co-operation before it is needed.

The importance of taking sufficient nourishment, however difficult or unpalatable he finds it, must be stressed.

The second period begins with the return of the patient from the operating room. Until consciousness is regained, the nurse must keep a careful watch to prevent him from dragging his needles out. As soon as he is conscious he should be propped up in bed on pillows. Atropine $\frac{1}{100}$ gr. given six hourly, helps greatly by reducing secretion. Inhalation of oxygen with 5 per cent. CO_2 for ten minutes each hour (later every two hours) during the day, and once in the middle of the night if the patient is awake, should be started as soon as possible after return to the ward. This is continued until normal breathing is restored and there is no pyrexia, but it may be continued for several days if chest complications threaten.

Sedatives are usually needed. Morphia gr. $\frac{1}{6}$ may be given in the first case, but should not be continued. For the first twenty-four hours nepenthe 30 minims in brandy may be required, but the pain is not usually severe. Later, simple drugs of the aspirin type generally suffice to keep the patient comfortable, though the addition of dial may be required at night to ensure sleep.

Opinions differ as to the wisdom of using drugs of the sulphonamide type as prophylaxis against bronchopneumonia in these cases, but if serious chest complications develop, streptocide may wisely be given intravenously.

As soon as he is fit, the patient may be allowed to get up in the ward. This makes treatment more tolerable and reduces the risk of hypostatic pneumonia.

The mouth must be kept as clean as possible throughout the period whilst the needles are *in situ*. Swabbing requires great care and frequent use of the hygienator is preferable. A mouth-wash should be available on the patient's locker, along with a bowl into which he may expectorate.

The nurse's most difficult task is to ensure that the patient takes sufficient nourishment. A resting adult requires about 1800 calories *per diem* to maintain his condition, and the delivery of so large a number of calories by fluids only is difficult. In the Manchester Radium Institute a special milk mixture (a modification of the Palmstierne solution) is given to the patients every two hours. A total quantity of three to four pints *per diem* is required to give the requisite calory intake. Patients find this very tedious and, as soon as they are able to take minced chicken, fish and custard, they are encouraged to do so. Nasal-œsophageal feeding is carried out when patients are unable to swallow.

Special milk diet ingredients

Milk	1000 grammes (1 litre)
Wheat flour	20 „
Butter	40 „
Glucose	30 „
The yolk of one egg	
Calorific value =	1100 calories per litre

The fat soluble vitamins are present in this diet, but the others have to be supplied extraneously. This is done by providing the patient with glucose-fruit drinks, and an occasional drink of tomato juice.

During the reaction phase, the patient's difficulties increase. The mouth becomes extremely tender, there is often increased salivation, and the sense of taste may be perverted or even be completely lost. The egg-milk mixture is unappetising and brandy added to the mixture to maintain the calories whilst reducing the volume is irritating. A combination of coaxing, sympathy, and hard driving is necessary to ensure that the patient gets sufficient nourishment. This task frequently falls upon the relatives, who should be warned of its importance.

Pain must be controlled by drugs, and sleep must be ensured. This may be the province of the private doctor, who requires to be informed about it by the radiotherapist, for otherwise he is very liable to withhold necessary drugs lest they have a deleterious effect upon radiation about which he is ignorant.

The foregoing brief summary of this very wide subject has been chiefly directed towards treatments by radium implantation. When moulds are used, the need for oral hygiene remains, but the risk of pneumonia is greatly reduced. Feeding problems are usually less troublesome, but they are equally important.

Finally, it is a fact that nursing plays so important a part in the treatment of oral cancer by radiation therapy, that patients have a considerably greater chance of survival in the hands of nurses with special experience in this work, than they have in ordinary general wards, although the radium treatment be carried out by the same therapist.

The reaction and the late appearances after radium treatment

The buccal mucosa does not exhibit the fine differences in reaction seen in the skin. A dose much below therapeutic levels may merely produce slight erythema, an effect sometimes seen in mucosa receiving a small amount of radiation when another part of the cavity is being irradiated. The usual reaction is a raised yellow fibrinous one, which is produced alike by sub-lethal doses and by doses which are almost at tissue tolerance level. A dangerously high dose produces a thicker fibrinous reaction which may take on bullous characters. This type of reaction is also seen after normal doses in very dirty or septic mouths, or where there has been added thermal or chemical irritation.

Although there is little difference in the appearance of the reactions produced by a wide range of doses, the length of persistence varies considerably. Starting in the second week, a normal mucosal reaction subsides in about six weeks. The reaction following a high dose may persist for several months, during which time slight trauma may precipitate radionecrosis. The effect of increase in irradiated volume upon tissue tolerance has already been mentioned. Occasionally a persistent reaction is seen in the mucosa overlying bone which is damaged and will subsequently sequestrate. Such reactions usually become frankly radionecrotic before expulsion of the sequestrum permits healing to take place.

Radionecrosis, which occasionally follows overdosage in the mouth, is generally painful, exquisitely tender and very slowly healing. Occasionally, when muscle is chiefly affected, pain may be insignificant or absent. Sepsis with suppuration frequently occurs. Bone necrosis may or may not be painful, but usually at some period it gives rise to severe distress, often with pain referred to the ear, in addition to that locally.

Block dissection, which offers the best chance of cure when operable secondary glands are present in the neck, should not be undertaken during the reaction period, so that a practical point of considerable importance arises when glands appear to be rapidly becoming inoperable. Delay may involve the loss of the patient's life but operation is fraught with serious danger to life from oral sepsis. Block dissection may so diminish the blood supply of the irradiated area that wide radionecrosis results, particularly if the floor of the mouth has been treated. The first two considerations are the province of the surgeon, but the latter is the concern of the radiotherapist. Close collaboration between surgeon and radiotherapist is necessary, in cases of this type, for no hard or fast rules of procedure can be laid down. Frequent observation of the reaction, and of the progress of the glands may permit of block dissection being carried out at the earliest safe time. Experience in the Manchester Radium Institute has not encouraged the practice of operating upon the neck first, and treating the mouth lesion as soon as the neck is healed, for then the disturbance of blood supply appears to impose severe limitations on the radiation.

The local end appearances of radium-treated mouth lesions are of interest because they vary in different parts of the mouth. The sites of small lesions in which there has been little loss of tissue and which have been treated by surface radiation, may be practically indistinguishable six months after treatment. If there has been tissue loss, a pale depression is left. When the dose has been carried almost to tissue tolerance, post-radiation fibrosis frequently occurs, a palpable mass lying beneath the pale, scarred surface. Determination of the nature of such a mass may be extremely difficult. The risk of biopsy precipitating radionecrosis is considerable, but if curative treatment of a recurrent lesion would be possible, this risk should be taken.

Deviation of the tongue towards the treated side, or limitation of protrusion, occurs fairly frequently. Palpable or visible evidence of scarring is then usually, but by no means invariably, evident.

The late result of irradiation of lesions of the oral surface of the cheek, or of the mucosa covering the ascending ramus of the mandible, is frequently pale scarring of tissue-paper like appearance, streaked with telangiectatic lines. This is seen after "tongue-pterygoid" implantations. Extensive implantations of the cheek may give rise to a pale, polished surface corrugated by fibrous plicæ overlying an area of induration.

Tissue-paper atrophy with telangiectasia is also seen in the floor of the mouth, but not infrequently mould treatments leave a normal appearance. This "normality" does not, however, extend to tolerance of further radiation.

The soft palate is frequently the site of a pale depression representing the position of the lesion, but post-treatment perforation occurs when the palate was already destroyed by neoplasm. Punctate late necrosis occasionally arises months, or even years, after radon seed implantation of the soft palate. This usually heals spontaneously with oral hygiene and avoidance of irritation.

The hard palate usually appears fairly normal after irradiation by a mould. Occasionally, however, a small dirty yellow patch of gelatinous incipient radionecrosis (similar to necrosis of the cartilage of the pinna) is seen, which persists for months, and may heal spontaneously or may break down and cause perforation. The appearance seems to be peculiar to this site in the mouth.

Normally irradiation of the alveoli produces a little smooth pale atrophy of the mucosa. Occasionally fibrous plicæ between alveolus and cheek develop. Over dosage, particularly in the presence of sepsis, is liable to cause bone necrosis which may occur after a prolonged fibrinous mucosal reaction, or may become evident months, or even years, after the mucosa has healed, and assumed an atrophied appearance. It is interesting to note that after sequestration, reformation of the jaw is occasionally seen.

As a generalisation it may be said that mould techniques employing moderate doses cause less permanent damage than results from implantation of radium. This fact probably contributes largely to the different appearances seen in various parts of the mouth. The safest end appearance, both from the point of view of permanent cure of the lesion, and of freedom from necrosis, would seem to be slight pale atrophy which is pliable, and free from marked telangiectasia. It follows doses of the order of 6500 r in seven days to medium-sized areas.

SUMMARY

PART II

The techniques of mould and implantation methods are described, radiographs of actual treatments being used in illustration. The need for good anæsthesia for implantation and the value of special post-treatment nursing are stressed.

REFERENCES

PART II

1 WALKER. *The Construction of Radium Applicators*, Murray, 1938.

2 PATERSON and MACVICAR. *Brit. Journ. Rad.*, Vol. xii, p. 452, 1938.

3 MELVILLE, A. G. G. *Brit. Journ Rad.*

4 HUTCHISON, R. G. Proceedings of Society of Radiotherapists of Great Britain and Ireland.

PROGRAMME OF MEETINGS

It is proposed to hold Ordinary Meetings of the British Institute of Radiology in 1943 as follows:—

Saturday, March 20.
Visit to the Royal Cancer Hospital (see page 85).

Saturday, April 17, 2.30 p.m.
"Experiences with Supervoltage X rays," by R. F. Philips, M.B., M.S., F.R.C.S., L.R.C.P., D.M.R.E., and G. S. Innes, B.Sc., A.M.I.E.E., A.Inst.P.

Saturday, May 22, 2.30 p.m.
Annual General Meeting, followed by an Ordinary Meeting.

SHORT DISTANCE X-RAY THERAPY WITH STANDARD APPARATUS: PHYSICAL FACTORS

By R. S. Quick, B.Sc., and J. E. Roberts, Ph.D., F.Inst. P.
Barnato Joel Laboratories, The Middlesex Hospital

Introduction

In recent years there has been considerable development in the treatment by X rays, generated at low voltages and applied at short focus-skin distances, of lesions on the skin or accessible either surgically or *via* body cavities. This has resulted in the production of apparatus specifically designed for this kind of work, the two best known types being the Siemens "Chaoul" tube and the Philips "Metalix tube for contact and cavity therapy." In both of these a very small shockproof tube is used, with the target as near to one end as possible. The former has a water-cooled transmission target with a normal focus-skin distance of 5 cm., while the latter has an air-cooled target which can be brought to within 2 cm. of the skin. Both tubes work in the region of 40 to 60 kV. The physical characteristics of the radiations from these tubes have been very fully investigated by Mayneord,[1] Lamerton,[2] and Braestrup and Blatz.[3]

In a recent paper in this Journal, Ffrancon Roberts[4] has suggested that many of the treatments normally carried out with true "Contact" apparatus can quite well be done with simple modification of standard apparatus. This applies in particular to superficial lesions, or those easily accessible without surgical interference. Owing to the difficulties of obtaining new apparatus, this may nowadays be of some importance. During recent years these Laboratories have been called upon to produce for the Meyerstein Institute of Radiotherapy several improvisations on these lines. The purpose of the present paper is to describe briefly the apparatus used and the physical characteristics of the radiation beams.

Short Distance "Contact" Therapy

One of the essential factors in contact therapy is the rapid decrease of depth dose in the first few centimetres of tissue. This results from a decrease in kilovoltage, and a reduction in focus-skin distance to about 5 cm. The latter change is probably the more important. Owing to the effect of the inverse square law, even a γ-ray beam at 5 cm. radium-skin distance gives little more than 50 per cent. depth dose at 2 cm. deep. A further effect of the inverse square law under these conditions is the rapid decrease of dose rate towards the edges of the treated field. This involves the restriction of the X-ray beam to fairly small diameters.

For "contact" therapy with ordinary apparatus we have used a standard Philips shockproof superficial therapy tube (Type 23850), capable of running continuously at 95 kV and 2·5 mA. This was excited by means of a 100 kV half-wave rectifying unit. It would have been possible to work at 5 or 6 cm. from the target, but, owing to the size of the shockproof tube housing, a focus-skin distance of 8 cm. was found to be much more convenient from the point of view of manipulation of the tube. Simple brass tubular applicators were made to fit in the place of the usual treatment cone. Each applicator had an appropriate lead stop to give fields of diameters 2·1, 2·6, 3·0, 3·6, and 4·0 cm.

Radiation Output and Quality

The filtration used for most purposes was 1 mm. aluminium, including the inherent tube filtration, said to be equivalent to 0·7 mm. Al. Under these conditions the output in air at 8 cm. is in the region of 220 r per minute. The skin dose-rate with the various applicators is given in Table I, showing a percentage backscatter varying from 3·5 to 12 per cent.

TABLE I

Surface Dose Rates (Contact)

95 kV. 2·5 mA. 1·0 mm. Al filter. 8 cm. F.S.D.

Applicator diameter	2·1 cm.	2·6 cm.	3·0 cm.	3·6 cm.	4·0 cm.
Surface dose-rate, r/min.	235	239	244	251	254
Backscatter per cent.	3·5	5·5	7·4	10·6	11·9

The output measured in air may be compared with those of special contact therapy tubes. This comparison, for a variety of conditions, is shown in Table II, the figures being taken from the works of Mayneord,[1] Braestrup and Blatz,[3] and Pendergrass.[5] From the point of view of radiation output, it will be seen that our tube may be regarded as intermediate between the Chaoul and Philips tubes.

In this region it is usual to measure radiation quality in terms of the half-value layer in aluminium. Under our standard conditions of 95 kV and 1 mm. Al filtration, the half-value layer was 1·5 mm. Al. In spite of the higher kV used, this is considerably lower than the values obtained with the Chaoul apparatus, probably owing to the relatively heavy filtration in the latter. It is possible, when required, to simulate more closely in quantity and quality the radiation from the Chaoul tube by the introduction of an additional filter of 0·07 mm. copper, keeping

the tension at 95 kV. This is shown in the last line of Table II, the higher kV of our apparatus being compensated by the greater focus-skin distance. This greater distance results further in increased uniformity of dose-rate across the beam. All output and quality measurements were made with a Victoreen Condenser Dosemeter calibrated over a wide range of radiation qualities by the National Physical Laboratory.

TABLE II

Apparatus	kV	Filter	F.S.D.	"Air" output r/min.	H.V.L. mm. Al
Chaoul	47	0·2 mm. Ni +2 mm. water	5 cm.	40	2·4
	54		5 cm.	70	
	57		5 cm.	97	3·3
Philips		———	2 cm.	7000 to 10,000	0·3
		1 mm. Al	2 cm.	1500	
		———	5 cm.	1100	
		1 mm. Al	5 cm.	250	
Meyerstein Institute	95	1 mm. Al	8 cm.	220	1·5
	95	1 mm. Al +0·07 mm. Cu	8 cm.	110	2·8

Percentage Depth Dose

Depth dose measurements for the "contact" radiation and others described later were carried out in a wax phantom of density very nearly unity. The phantom was made up in sheets of various thicknesses, one sheet being moulded to take the Victoreen chamber half submerged for surface measurements. The ionisation chamber used was 1·3 cm. long by 0·9 cm. diameter externally. This is rather large for work at small focal distances, but no serious errors appear to have been introduced.

For our standard conditions, the percentage depth doses down to 5 cm., for the central axis of a 4 cm. diameter field, are given in curve 1 of Fig. 1. Curve 3, drawn from Mayneord's published figures, shows the corresponding results for the Chaoul tube at 60 kV and 5 cm. F.S.D. It will be seen that the depth doses are of the same order in the two cases. The differences in shape of the two curves are probably due to the very great differences in the spectral distributions of the radiations, and to the change in focus-skin distance. The use of the higher voltage, lightly filtered radiation at 8 cm. F.S.D., instead of 5 cm., gives somewhat greater depth doses down to 4 cm., owing to the smaller inverse square law decrease with distance. Beyond 4 cm. depth, the greater absorbability of this radiation causes a rather more rapid fall in depth dose than with the Chaoul radiation.

By adding 0·07 mm. copper to the filter the Chaoul radiation is approximately reproduced in quantity and quality. Under these conditions the depth dose variation is shown in curve 2 of Fig. 1. Owing to the greater focus-skin distance, this curve shows, in general, slightly higher depth doses than curve 3.

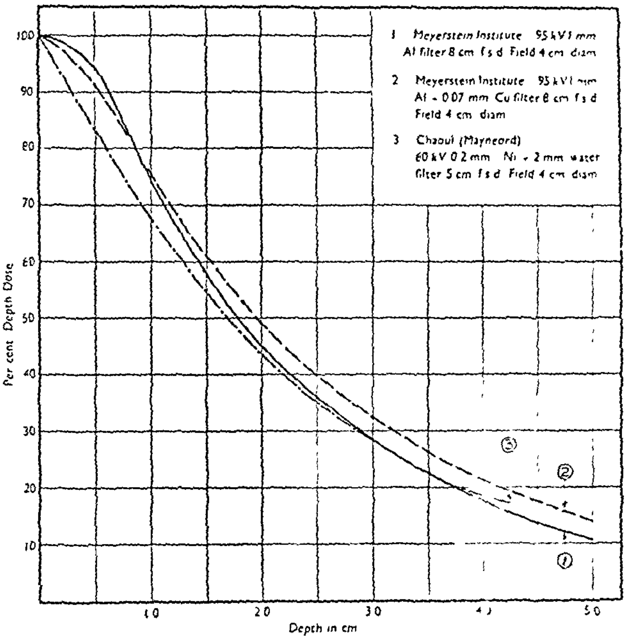

FIG. 1.
Depth Dose in Short Distance Technique.

"Middle Distance" Superficial Therapy

A large proportion of the treatments carried out with "contact" apparatus consists of applications with a single skin field. In such treatments the aim is to give a lethal dose of radiation to the deepest pathological tissue, and the overlying tissues, of necessity, receive considerably more than this dose. For lesions up to a few millimetres in thickness and reaching up to the surface, this is of no consequence. Some cases, however, arise in which it is desirable that the lethal dose should reach somewhat greater depths, say 1 or 2 cm., and that the overlying tissues should not be very greatly over-irradiated. At the same time it is desirable that the dose-rate at greater depths should fall off as rapidly as possible. This type of treatment clearly requires some compromise between the standard "deep" and the "contact" techniques. For this purpose we have constructed simple, short distance, small field applicators to fit our 200 kV therapy tubes. Each applicator consists of a brass tube with an appropriate lead stop at the target end. They can be attached to a standard base which fits the X-ray tube housing in the same way as an ordinary applicator. The tube of the applicator is readily detachable for cleaning purposes. Most of our work was carried out on Siemens' "Doglass" shockproof tubes at 200 kV constant potential and 0·5 mm. copper filtration. With these tubes the

most satisfactory focus-skin distance was found to be 22·5 cm. Shorter distances are possible, but are not so convenient for manipulation. More recently, the technique has been applied to the Metropolitan Vickers continuously evacuated tubes, but in this case, owing to the larger tube size, the focus-skin distance was increased to 26 cm. Average operating conditions for the two types of tube are then as follows:—

Apparatus	kV	mA	Filter	H.V.L.	F.S.D.	Skin dose rate	
						2 cm. field	5 cm. field
Siemens	200 const.	6	0·5 mm. Cu	1·1 mm. Cu	22·5 cm.	122 r/min.	133 r/min.
Metro-Vickers	200 const.	10	1·0 mm. Fe	1·3 mm. Cu	26·0 cm.	197 r/min.	232 r/min.

It will be seen that the higher kV, combined with the larger F.S.D., results in dose rates of the same order as those used in "contact" therapy.

Percentage Depth Dose

Some typical depth dose curves for these improvised "middle distance" conditions are given in Fig. 2. Comparison with Fig. 1 shows that these curves are much less steep than those for "contact" conditions. They therefore fulfil more nearly the requirements for the single field treatment of the less superficial lesions. If, for instance, it is required to give a dose of 5000 r to the base of a lesion at 2 cm. depth, a skin dose of roughly 6670 r will be needed. For the same depth dose with the contact apparatus it would be necessary to apply a skin dose of 11,000 r. At the same time it should be borne in mind that with the more penetrating beam the deeper underlying tissues receive a greater dose than before, though in most cases this should not be a serious matter.

Physical investigations on "middle distance" therapy have been described recently by Lamerton.[6] In this case the generator used was the Victor KX-10, and the tube Victor SP-140, specially designed for this type of work. The working conditions were 140 kVp (half wave), 5 mA, 0·25 mm. copper filter, giving an output in air at 20 cm. distance of about 50 r/minute, and a half-value layer of 0·33 mm. Cu. For comparison purposes, a depth dose curve under these conditions with a 4 cm. diameter skin field is included in Fig. 2. It will be seen that the depth doses are of the same order as those obtained with our apparatus, the rather higher values of the latter being due to the harder radiation and somewhat greater distances used.

Intra-cavity Therapy

One of the advantages of the standard types of "contact" apparatus is their suitability for use within body cavities, natural or artificial. Such treatments are beyond the range of the improvised "contact" apparatus described in the first section. It has, however, been pointed out by Hayes Martin[7] that there are some cases of this nature for which a "middle distance" technique is more suitable. This appears to be particularly so in the case of lesions in the mouth. We have, therefore, constructed a modified form of "middle distance" applicator for this purpose. Following the lines laid down by Hayes Martin, the applicator is now divided into two parts (Fig. 3). The tubular applicator proper (1), now a separate unit, can be placed over the area to be treated and held there whilst the X-ray tube is brought into position. When this is done, the X-ray beam is brought into line; the final adjustment is to slide a sleeve (2) attached to the X-ray tube aperture

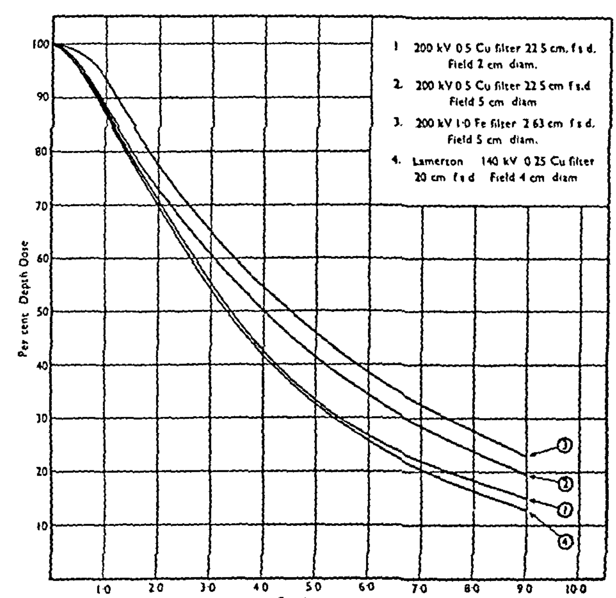

Fig. 2.
Depth Dose in Middle Distance Technique.

over the applicator, and to lock the whole in position. One of the difficulties in this arrangement is in the exact location of the applicator end over the area to be treated. To overcome this, Hayes Martin uses a small periscope with internal illumination, which is inserted through a hole in the applicator side. We have found a somewhat simpler arrangement quite satisfactory. A small lamp and mirror are mounted

together on the end of a rod, and this is inserted through a half-inch hole in the side of the applicator. With careful manipulation, a clear view is obtained of the area of the lesion enclosed by the applicator end.

For most purposes two sizes of applicator, with diameters 2·8 cm. and 3·3 cm., have been found to be sufficient. In each size there are two types, one with a straight end and the other with the end cut away at about 30 degrees. The projecting edge of

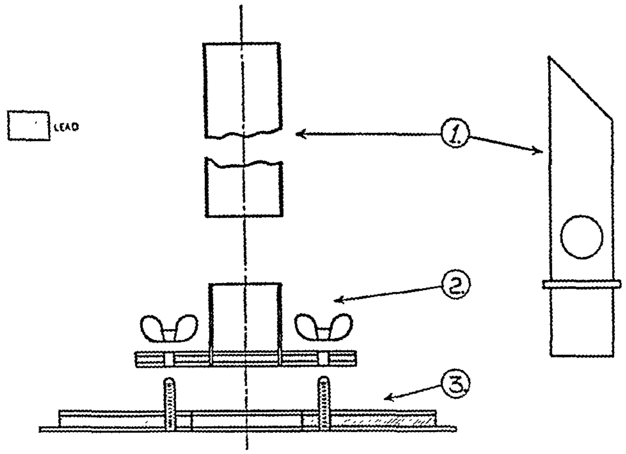

FIG. 3.
Intra-cavity Applicator.

the latter serves as a tongue depressor and to support soft tissues outside the X-ray beam. It was found necessary to use rather larger focus-skin distances for intra-cavity work than for superficial treatments, and 35 cm. was chosen as the most convenient distance. The usual working conditions were then:

Set I. 180 kV, 6 mA, 0·5 mm.Cu filter, 35 cm. F.S.D., surface dose-rate 47 r/minute.

Set II. 200 kV, 10 mA, 1·0 mm. Fefilter, 35 cm. F.S.D., surface dose-rate 100 r/minute.

In some cases the filtration on Set II was increased by the addition of 0·4 mm. Tin. This increases the half-value layer of the radiation to 2·0 mm. Cu, and reduces the surface dose-rate to 45 r/minute.

Depth dose measurements have been made under these conditions, and it was found that the curves differed by only one or two units from the corresponding "middle-distance" conditions shown in Fig. 2. The discussion in that section applies, therefore, equally well to the treatment with single fields of intra-buccal lesions, using this apparatus.

ACKNOWLEDGMENTS

Much of the experimental work here described was carried out in the Meyerstein Institute of Radiotherapy at the Middlesex Hospital. The authors wish to express to the Senior Medical Officer, Mr. B. W. Windeyer, and his colleagues, their gratitude for the facilities made available, and for their sustained interest in the work.

SUMMARY

Simple modifications of standard X-ray apparatus are described for carrying out short distance "contact" therapy. For work requiring somewhat higher penetrations, a number of "middle distance" small field applicators for use on standard 200 kV therapy tubes are described. Radiation output, quality and depth dose measurements on the beams so produced have been made. Modifications of the "middle distance" applicators for intra-buccal treatments are described.

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PROGRAMME OF ORDINARY MEETING—March 20, 1943

AS already announced, an Ordinary Meeting of the British Institute of Radiology will be held at the Royal Cancer Hospital (Free), Fulham Road, London, S.W.3, on Saturday, March 20, 1943.

Outline of programme as below:—

10.15 a.m.	Informal Reception by the President of the Hospital, Mr. Chester Beatty.
10.45 a.m.	Paper by Professor W. V. Mayneord on "Isodose Surfaces."
11.30 a.m. to 12.30 p.m.	Demonstrations in the Physics Department.
12.30 p.m. to 1.15 p.m.	Light lunch at the Hospital.
1.30 p.m. to 2 p.m.	Paper by Dr. D. W. Smithers on "X-ray treatment of carcinoma of the œsophagus."
2 p.m. to 2.30 p.m.	Paper by Dr. M. Lederman on "Radium treatment of intrinsic cancer of the larynx."
2.30 p.m. to 4 p.m.	Demonstrations in Clinical Departments of Radiotherapeutic, Diagnostic, and Pathological work of the Hospital.
4 p.m.	Tea.

The Secretary of the Hospital would be grateful if members wishing to attend would notify him before Friday, March 12, 1943.

PYELOGRAPHY AND THE SPACE-FILLING LESION

CARBUNCLE OF THE KIDNEY

A Case Report

By LIEUT. C. J. HODSON, M.B., B.S., M.R.C.P., D.M.R.E., R.A.M.C.

THE following case is submitted to draw attention once more to the fact that there are a variety of problems in which radiological and clinical evidence are both of equal importance in arriving at a diagnosis, a consideration of each by itself tending towards mystification or an erroneous conclusion.

FIG. 1.

Its further interest lies in the fact that the condition, of benign outlook itself, closely mimics the early stage of one of the most malignant of known diseases, and being relatively uncommon compared with the malignant lesion, is apt not to be considered.

G.B., aged 22 years, and at the time slightly run down in health, noticed a small pustule over his right eyebrow. This cleared up in the usual way, but his general health remained poor, and during the following three weeks he noticed vague pains in his left loin, which became constant and assumed a dull, aching character.

At the end of this time (22.4.42) he had a shivering fit and went to bed. He felt ill, his head ached, there was evening pyrexia and night sweats. The pain in the loin continued with occasional short periods of considerable severity, and radiated downward to the sacral and iliac regions. It was worse on active movement of the left leg.

The following week (27.4.42) a trace of albumen was found in his urine.

On examination, the only abdominal signs were tenderness and enlargement of the left kidney, and a provisional diagnosis of Grawitz tumour was considered. A chest X ray was clear. Urine:—Faint cloud of albumen and a few W.B.Cs. Culture sterile. No K.L.B. organisms seen. A blood count (1.5.42) showed 15,000 W.B.Cs. per cm. (75 per cent. polymorphs).

9.5.42. Intravenous pyelography. There was a deformity of the left renal pelvis, with non-visualisation of the middle calyx, and a slight impairment of function, judged by dye excretion. The appearances were such that the nature of the lesion was suspected, and taken in conjunction with the clinical evidence, a diagnosis of carbuncle of the kidney was made.

18.5.42. The patient had lost much weight, he felt weak and ill, the pain was still severe at times and his temperature was still elevated. Blood count W.B.Cs. 14,000 (67 per cent. polymorphs).

From this time his condition slowly improved. The pain became less intense and eventually ceased. He commenced to put on weight, his appetite increased, and apart from two attacks of fever associated with pain, firstly in the right shoulder, secondly in the left chest, his temperature returned to normal. Recovery to a robust state of health and normal renal function was uneventful.

At no time was there evidence of the lesion having discharged its contents.

A second intravenous pyelogram (8.6.42) showed improved function of the left kidney and an appreciable degree of return to anatomical normality.

Treatment was commenced on 27.4.42 with Rubiazol 1 g. four-hourly for two days, and on 15.5.42 he was given intensive sulphathiazole therapy for five days with marked effect on his temperature.

CONCLUSIONS

In this case radiological examination showed a poorly functioning kidney with a space-filling lesion present. The nature of this was arrived at only by consideration of the history and full clinical picture. The signs of a pyogenic process (rigor, pain, sweats, leucocytosis and pyrexia) served to distinguish its nature from a tumourous condition. The course of the disease process could be followed by repeated pyelography.

ACKNOWLEDGMENTS

My thanks are due to Dr. A. Hope Gosse and Dr. Courtney Gage for permission to publish this case.

A RADIOGRAPHICAL COMPARISON OF THE PITUITARY FOSSA IN MALE AND FEMALE WHITES AND NEGROES

By HAROLD BURROWS, F.R.C.S., A. J. E. CAVE, M.D., and KATHLEEN PARBURY
(*Museum, Royal College of Surgeons of England*)

IN an attempt to discover possible sexual and racial differences in the configuration of the pituitary fossa in white and negro crania, a radiographic study was made, under uniform conditions, of 100 adult crania, and the outlines of the fossæ in the median sagittal plane were obtained. During exposure each skull, suspended from supports inserted into the external auditory meatuses, was so orientated that its sagittal plane remained permanently at right-angles, and in a constant position relative, to both the source of X rays and the photographic film. Throughout the study the distances between the source of X-rays, the cranial sagittal plane and the photographic film were kept constant, *i.e.*, in every instance the X-ray tube anode was 180 cm. distant from the photographic film, and the film 8·8 cm. distant from the median plane of the skull. Distortion was therefore minimal, and the photographic outlines thus obtained of the several pituitary fossæ were directly comparable as to size and shape.

From the radiographs two kinds of measurement were made, as follows:—Firstly, the outlines of the fossæ were transferred to stiff paper of uniform thickness, from which silhouettes, representing the sagittal pituitary "area," were then cut out and weighed. These silhouettes (Figs. 1, 2, 3, 4) afforded visual and mechanical evidence concerning variations in pituitary fossa configuration and sagittal area.

TABLE I
(Sixty-nine skulls of known sex)

	No. of skulls	Average weight of paper silhouettes in mg.	Relative percentages taking Male White as 100
Male white	30	0·1020	100·00
Female white	5	0·0860	84·31
Male black ..	20	0·0895	87·74
Female black	14	0·0791	77·54
	69		

TABLE II
Twenty-one skulls
(Sexed with probability)

	No. of skulls	Average weight of paper silhouettes in mg.	Relative percentages taking Male White (Table I) as 100
Male white	3	0·0943	92·45
Female white	7	0·0889	87·15
Male black ..	7	0·0764	74·90
Female black	4	0·0702	68·82
	21		

TABLE III
(Comprising the ninety skulls of the preceding Tables)

	No. of skulls	Average weight of paper silhouettes in mg.	Relative percentages taking Male White as 100
Male white	33	0·1013	100·00
Female white	12	0·0877	86·64
Male black ..	27	0·0861	84·99
Female black	18	0·0771	76·11
	90		

TABLE IV
(Average length and depth, in mm., of pituitary fossa)

	No. of skulls	Average Length	Average Depth	Product	Ratio, taking Male White as 100
Male white	30	11·05	7·49	82·76	100·00
Female white	5	10·79	6·98	75·31	90·99
Male black ..	20	11·18	7·18	80·27	96·10
Female black	14	10·17	6·79	69·05	83·43
	69				

Secondly, the two principal diameters, antero-posterior length and depth, of the fossæ were measured directly, the latter dimension being taken as the maximum measurement obtainable at right-angles to the former.

For the four cranial groups examined (*i.e.*, male white, female white, male black, female black) the comparative areas of the silhouettes are given in Tables I, II, and III; the dimensions of the pituitary fossa appear in Table IV.

Of the 100 skulls selected for investigation, fifty were African negro of known locality and fifty were

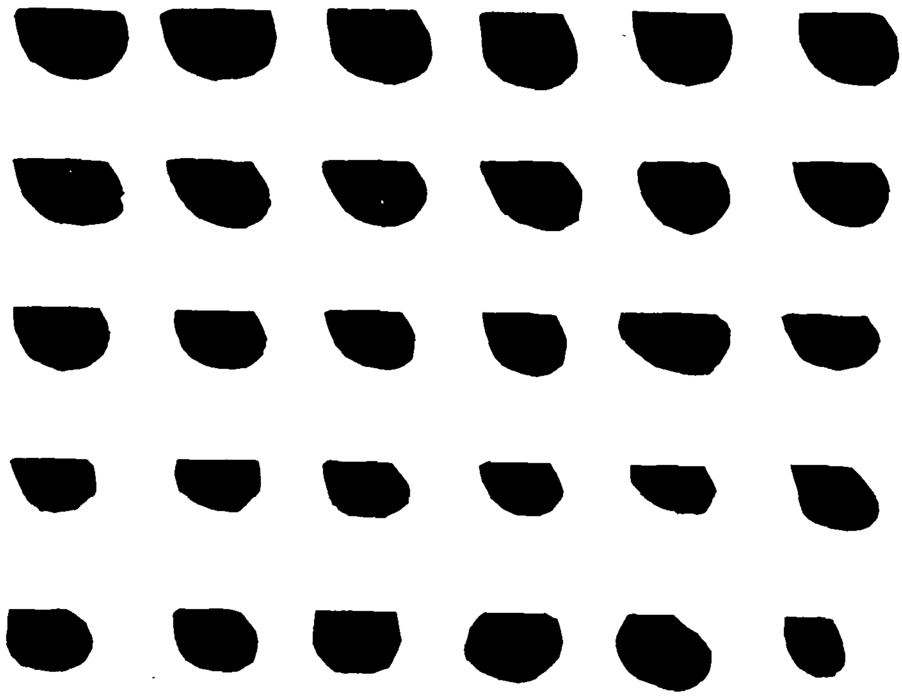


Fig. 1.
Pituitary fossa silhouettes of thirty male white crania.
(The anterior end of the fossa is to the left throughout.)

British, from an old (post-medieval) London burial ground; sixty-nine were sexed with confidence either from their records or on morphological grounds; twenty-one others were sexed tentatively, and a further ten could not be sexed. The radiographs of this last group were therefore discarded. Neither the African nor the British series comprised crania of anthropological uniformity, and, of the two, the latter was probably the more homogeneous in this respect.

It will be noted that the sequence of relative percentages follows a corresponding course in Tables I and IV (skulls of known sex), whereas a different sequence obtains in Tables II and III, based wholly or partly on doubtfully sexed skulls. Due allowance being made, however, for accuracy of sexing, the figures given do indicate the area of the pituitary fossa, as estimated in the sagittal plane, to be greater in the male (white or black) than in the female, and to be greater in the European than in the African of corresponding sex. The ratios of females to males, expressed as percentages, are 84·31 in the whites, and 88·37 in the negroes.

As Figs. 1 to 4 would suggest, linear mensuration of the pituitary fossa is somewhat unsatisfactory in both execution and interpretation, the basis cranii being constructed to subserve physiological function rather than the convenience of the craniologist. Thus in many instances the anterior extremity of the fossa shelves so gradually that it becomes impossible to define any anterior terminal point for the long diameter of the hollow, whilst the fossa floor is so variable in configuration that its determined maximal depth constitutes but an unreliable indicator of sagittal area. Obviously, too, the size of the pituitary fossa, however estimated, is no direct index of pituitary gland bulk or volume, since criteria are wanting concerning the precise allowance to be made for meningeal, vascular and other factors. Nevertheless, the size of the fossa must bear a reasonable and tolerably constant relationship to that of the contained organ (much as cranial capacity does to brain volume) and the lack of any certain correlation between the two is no argument for rejecting conclusions based upon fossa dimensions, particularly when, as here, skeletal material only is available for study. The determination of brain- and pituitary-volume correlation by the taking of endocranial and pituitary-fossa casts is

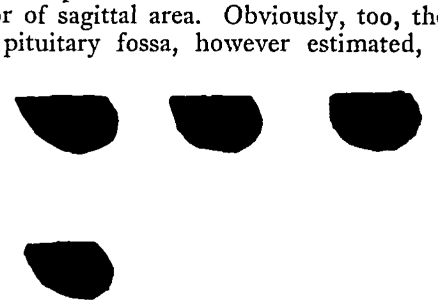


Fig. 2.
Pituitary fossa silhouettes of four female white crania.
(A fifth silhouette was lost. Left = anterior.)

FIG. 3.
Pituitary fossa silhouettes of twenty male black crania.
(Left = anterior.)

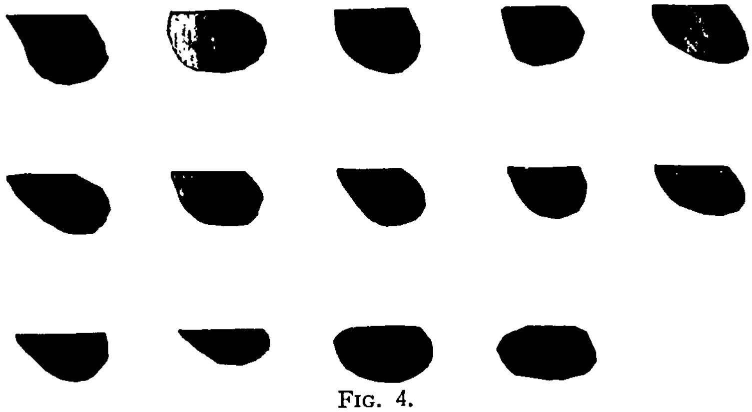


FIG. 4.
Pituitary fossa silhouettes of fourteen female black crania.
(Left = anterior.)

an accepted and legitimate procedure in palæontological research, and is indeed often the sole approach possible. Whilst, therefore, the methods here employed for the assessment of pituitary dimensions may lack ultimate precision and perfection, they are nevertheless submitted as at least sufficiently accurate and as a reliable basis for conclusions.

That, in the material examined, the estimated pituitary fossa area of the males should exceed that of the females appears noteworthy, especially since, in an examination of various animal species, the reverse was found to obtain, and this despite the (generally) lesser relative bulk of the female body and brain. Another obtrusive point of interest is the wide individual variation in size and shape manifested by the pituitary fossa. Very probably such variation is dependent, to no small degree, upon purely anthropological or racial factors (*i.e.*, type and build of cranium) as well as upon sexual and intrinsic (*i.e.*, vascular and other) factors. The matter is worthy of further attention. Its projected investigation by us was negatived by the destruction by enemy action of the necessary cranial material, a disaster which necessarily curtailed the original scope and aims of this paper. Limited therefore though the data presented are, they are advanced as not wholly devoid of interest and significance.

ACKNOWLEDGMENTS

Our grateful thanks are accorded the Medical Research Council for a grant defraying the cost of this investigation, to the Victor X-ray Corporation Limited, for the generous loan of radiographic apparatus, and to the Council of the Royal College of Surgeons of England for facilities and for permission to use material from their museum.

SUMMARY

The method, and the results, of standard radiographic examination of the adult pituitary fossæ of fifty African negro and fifty British (old London) skulls are described. The appearances and dimensions of the pituitary fossæ in the median sagittal plane are assessed, described and analysed. Racial and sexual differences are noted. Both in the whites and the negroes, the male fossa is larger than the female; for the corresponding sexes the fossa is also larger in the Europeans than in the Africans.

MATERIALS FOR DEPTH DOSE MEASUREMENT

By F. W. Spiers, Ph.D.
The General Infirmary, Leeds

Introduction

THIS investigation began with an attempt to find a powder which would be suitable as a filling medium for depth dose measurements in hollow anatomical models. It was soon realised, however, that a critical survey was needed of the various materials suggested and used for depth dose measurement, taking into account the effects of electron density and effective atomic number. A study was first made of substances of known chemical composition and a suitable powder mixture was suggested by this work, which proved to be satisfactory when tested experimentally. Application of experimental methods to materials of indefinite or unknown composition extended the examination to such materials as waxes and "pressdwoods."

Theoretical Considerations

Analysis of depth dose data shows that the radiation dose at any point in a medium is made up of two components, a contribution from the primary beam and a scatter contribution arising from the surrounding medium through which the primary beam passes. With increasing depth and size of field the scatter contribution assumes a greater proportion of the total dose. The primary contribution depends directly on a factor $e^{-\mu d}$, where μ is the total absorption coefficient for the primary wavelength; the scatter contribution is very much more complex. It depends partly on the same factor $e^{-\mu d}$, since this determines the order of the primary radiation which gives rise to the scatter, and partly on some function of σ_S/μ' and the field size[1]; here μ' should refer to the longer wavelengths associated with various angles of scatter. Both absorption and scatter coefficients have roughly constant values over a range of light substances of unit density, but they differ sufficiently to give rise to appreciable discrepancies when depth doses measured in various media are compared with those in water. In spite of the inconvenience of a liquid medium, water must still be regarded as the most reliable and universal standard for depth dose measurements. Quimby and others[2,3] have reported considerable differences in depth doses measured in wax and water, and have shown that these occur in both the primary and scatter contributions. Moreover, if a medium differs from water in its absorption and scatter properties, it is not possible to apply satisfactory corrections which will allow for such differences and reduce observations to a common standard. It follows that a given medium can only compare accurately with water if both the absorption and scatter coefficients for the medium agree with the water values over a wide range of wavelength. It is also unlikely that the criterion of density can alone be adequate to test the properties of the medium, since the fundamental factors concerned are the electron density and the effective atomic number. Accordingly a number of substances of known chemical composition were examined and calculations made of their electron densities and effective atomic numbers. These constants were then used to calculate absorption and scatter coefficients, which could be compared with corresponding values for water. The formulæ used are set out below:—

Electron density:

$$n = 6{\cdot}06 \times 10^{23}\, n_m\, \rho/M \quad \text{electrons/c.c.} \qquad (1)$$

where n_m is the number of electrons in the molecule of weight M and ρ is the density in gm./c.c.

Effective atomic number[4,5]*:*

$$\overline{Z} = \sqrt[2\cdot 94]{\Sigma(a_1\, z_1^{2\cdot 94})} \qquad (2)$$

where a_1 is the fractional content of electrons for the element z_1, the summation being for all the elements present in the compound.

Linear absorption coefficient[5,6]*:*

$$\mu = n\,({}_e\sigma + {}_e\tau) = n({}_e\sigma + 2{\cdot}64 \times 10^{-26}\, \overline{Z}^{2\cdot 94}\, \lambda^3) \qquad (3)$$

Here it has been convenient to use the absorption coefficient per electron, ${}_e\tau$, instead of the more usual atomic coefficient $Z_e\tau$, since the electron density n can then be taken out as a common factor.

Scatter coefficient: $\sigma_S = n \times {}_e\sigma_S$ (4)

In (3) and (4) the values of the scatter-absorption coefficient per electron, ${}_e\sigma$, and the scatter coefficient per electron, ${}_e\sigma_S$, have been calculated from the Klein Nishina formulæ.

The density factor in (1) refers to the material in bulk, and for a powder its value would be indefinite if any degree of mechanical pressure were applied. The use of a powder as a phantom material or in "bolus" bags, however, entails only a packing down of the powder under its own weight, with little or no external pressure. Hence the powder bulk densities were determined by shaking down in a measuring cylinder until a minimum volume was attained and then weighing. This method gave consistent results both for single powders and mixtures; the values obtained together with the constants calculated by formulæ (1) and (2) are listed in Table I. Some of the substances are familiar as materials for filling bolus bags, for "building up" a treated part to form a complete phantom and for depth dose measurements; others were included in the examination as

TABLE I

Material	Chemical Formula	Bulk Density	Electron Density	Effective Atomic Number
Water	H_2O	1·00 gm./c.c.	3·36 × 10^{23}/c.c.	7·42
Ground rice ..	$(C_6H_{10}O_5)_n$	0·78	2·51	6·89
Pearl rice	"	0·91	2·93	6·89
Sugar	$(C_6H_{12}O_6)_n$	0·96	3·10	6·94
Borax	$Na_2B_4O_7 . 10H_2O$	0·95	2·99	7·99
Sodium bicarbonate	$NaHCO_3$	1·21	3·67	8·75
Boric acid	H_3BO_3	0·82	2·57	7·29
Kaolin	$Al_2O_3SiO_2 . 2H_2O$	0·40	1·22	10·07
Paraffin wax ..	$C_{16}H_{34}$	0·92	3·20	5·41
"Tissue"	*see ref.* (4)	1·00	3·34	7·33
Mixture 1	63% rice, 37% $NaHCO_3$	1·06	3·34	7·65
Mixture 2	78% rice, 22% $NaHCO_3$	0·99	3·15	7·48

possible light materials which might compare satisfactorily with water. It is noticeable that the effective atomic number of paraffin wax is very low and that, with the exception of sodium bicarbonate, all the electron densities are less than the water value. Rice appears as perhaps the most disappointing of the commonly used materials, the bulk densities for both pearl and ground rice are decidedly less than unity, with consequent low electron densities, and these deficiencies are accompanied by a somewhat low atomic number. The values for the tissue, having an assumed average composition[4] and unit density, agree very closely with those for water. The formulæ in (3) and (4) were used to calculate values of μ and σ_S for most of the materials in Table I, and the results are shown in Figs. 1 and 2 for the wavelength range 0·02 to 1 Å. Fig. 1 shows

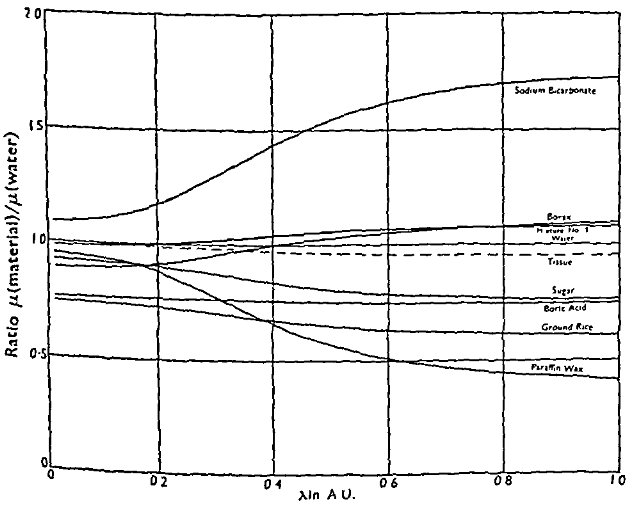


FIG. 1.

the ratio μ (material)/μ (water) as a function of the wavelength; at short wavelengths these absorption ratios differ from unity by amounts which depend only on the electron density of the materials, but for wavelengths longer than 0·1 Å these variations, in general, increase owing to the effect of the differences in atomic number. Paraffin wax and sodium bicarbonate show the most marked variation with wavelength and "tissue" the least. At the wavelength 0·165 Å used by Quimby[2] the paraffin wax curve is some 10 per cent. below water; the absolute difference in μ is approximately 0·02, which, on consideration of the absorption factor alone, would put the depth dose at 10 cm., some 20 per cent. higher in wax than in water; differences of this order were in fact observed.

Variations in the scatter contribution for different materials are much harder to assess; to a limited extent the factor σ_S/μ indicates the nature of the difference to be expected, but other factors such as field size, depth, and degradation of the scattered radiation affect the contribution so considerably that only a rough estimate is possible. In Fig. 2 the ratio σ_S/μ (material) / σ_S/μ (water) is shown as a

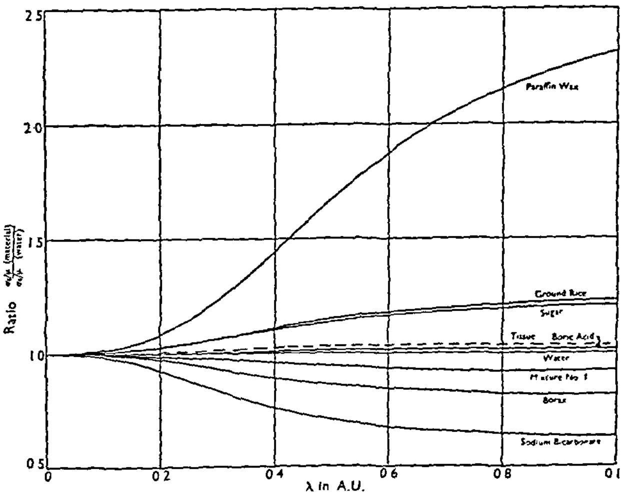


FIG. 2.

function of the wavelength. The curve for wax shows that the scatter should be in excess of that for water; at the wavelength 0·165 Å the additional scatter for wax would be about 5 per cent., and this is the order of the increase in surface back scatter observed by Quimby.[2]

In view of the opposite tendencies of both the

absorption and scatter curves for rice and sodium bicarbonate, mixtures of these two powders were investigated. The resulting density variation is shown in Fig. 3; the curve shows a maximum density greater than either component at the mixture containing 80 per cent. sodium bicarbonate owing to the fact that the latter powder has a smaller particle size than the rice. A mixture was chosen by trial to give values of μ and σ_s which were almost identical with the water values at a wavelength 0·13 Å, the

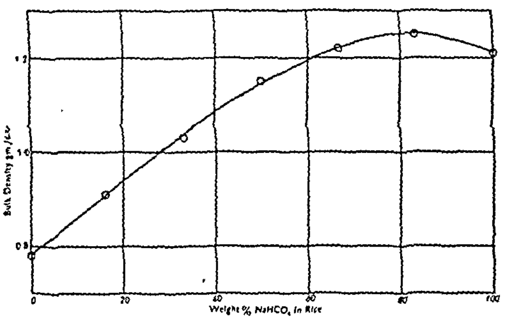


Fig. 3.

average wavelength for 200 kV deep therapy. This is mixture No. 1 in Table I, and the complete curves for it are shown in Figs. 1 and 2. Incidentally the bulk density of this mixture is 1·06 gm./c.c., but this is, of course, immaterial as long as the values of μ and σ_s are correct. A second mixture No. 2 is also in the list; it was chosen to give an effective atomic number nearer to the value for water, but this was only gained at the expense of a lowered electron density.

Experimental Tests of Powder Mixture

Mixture No. 1, containing 63 per cent. by weight of rice and 37 per cent. sodium bicarbonate, appeared promising as a dry powder for depth dose measurements and as a more satisfactory filling for bolus bags than any of the single substances at present in use. Below 0·2 Å the absorption and scatter coefficients of this mixture are almost identical with those of water, and only for wavelengths beyond 0·4 Å do the differences exceed 5 per cent. up to maximum values of about 8 per cent. at 1 Å. Depth dose measurements were therefore made to compare this and other mixtures of rice and sodium bicarbonate with water. This section of the work was carried out in the Physics Department of the Royal Cancer Hospital, where Professor W. V. Mayneord very kindly offered facilities for the use of X-ray apparatus which were temporarily unavailable in Leeds.

The measurements were made with a Mecapion dosemeter in a cubical tank, of 30 cm. side, which could be filled with water or powder. Owing to the difficulty of moving an ionisation chamber about in a powder, the chamber was inserted in a thin close-fitting celluloid tube, fixed centrally in the tank, which could then be filled to known depths with the medium under test. Care was taken to ensure that the primary beam was at all points well within the medium, and that an adequate depth of 10 cm. of medium existed below the chamber. Although the dimensions of the phantom were somewhat smaller than usual, the aim was to compare measurements in several media under identical experimental conditions.

The first experiments were carried out at 200 kV (constant potential) with other radiation factors as follows: filter 1·1 mm. Cu, H.V.L. 1·5 mm. Cu, F.S.D. 48 cm., diameter of the circular field 15 cm. The ground rice and sodium bicarbonate powders had the same bulk densities as the samples tested in Leeds, and the density curve in Fig. 3 was rechecked. Depth dose curves were first taken in

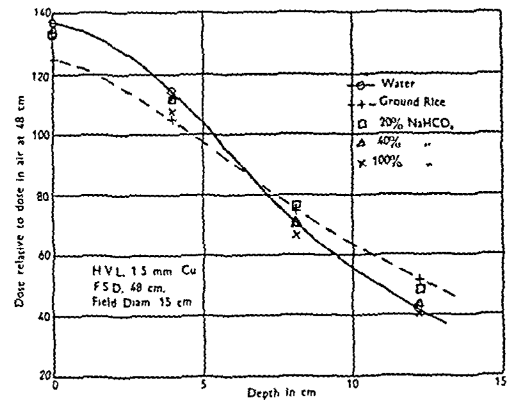


Fig. 4.

water and in the ground rice powder. Sodium bicarbonate was then added to the rice powder, and further measurements made upon well mixed powders containing 10, 20, 35 and 40 per cent. sodium bicarbonate. Finally a depth dose curve was taken in pure sodium bicarbonate. Fig. 4 illustrates the results for water, the two components separately and the 20 per cent. and 40 per cent. mixtures, the doses being plotted relative to the dose in air at the F.S.D. used. It will be seen that the rice powder produced only 25 per cent. surface backscatter compared with 37 per cent. for water, but

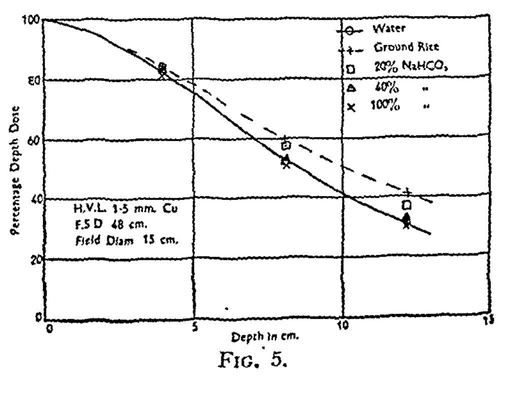


Fig. 5.

that with increasing depth the higher transmission in the rice more than compensated for the loss of scatter. The lower surface scatter for rice is contrary to the σ_S/μ curve in Fig. 2, but the actual back-scatter values are approximately in the proportion of the electron densities upon which σ_S depends (Table I). Percentage depth dose curves are plotted in Fig. 5, from which it will be seen that D_{10} for rice is some 22 per cent. higher than for water. Additions of sodium bicarbonate were found to raise the value of the surface scatter and lower the transmission, the mixture containing 40 per cent. sodium bicarbonate giving absolute doses in agreement with the water curve to an accuracy of ± 3 per cent. at all depths investigated. The composition of this mixture is close to the optimum calculated in the

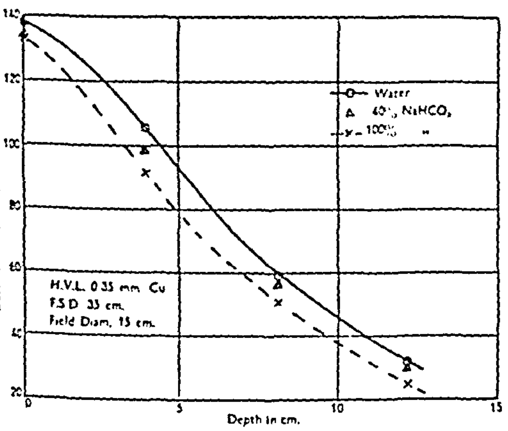


FIG. 6.

first part of the paper, and can be regarded as a simple prescription for a powder which will behave practically as water in the deep therapy X-ray region. The phantom composed entirely of sodium bicarbonate produced rather less scatter and a lower transmission than water, but not to anything like the degree suggested by the simple theoretical treatment.

The 40 per cent. mixture was also tested at the wavelength region of about 0·25 Å by using the following conditions: 125 kV (constant potential), filter 0·27 mm. Cu, H.V.L. 0·35 mm. Cu, F.S.D. 35 cm. and field diameter 15 cm. These results, again referred to the free air dose, are shown in Fig. 6 together with the curve for a sodium bicarbonate phantom. The absolute doses for the 40 per cent. mixture are now uniformly low, less scatter and more absorption being apparent, with an average deficiency of approximately 5 per cent. for all depths. The sodium bicarbonate alone shows much more absorption at this longer wavelength.

EXAMINATION OF MATERIALS OF UNKNOWN COMPOSITION

The theoretical and experimental studies reported above showed that the absorption and scatter properties of a medium depended so considerably on the combined effects of chemical composition and density that similar tests should be extended to a number of substances of unknown or indefinite composition, such as mixed waxes and the recently used medium "pressdwood." For these materials the bulk density is usually stated to be approximately unity, but no other information as to electron density or effective atomic number can be given, which would enable absorption and scatter coefficients to be calculated. Both the electron density and the effective atomic number can, however, be determined experimentally without too much difficulty, as will be seen from the following considerations.

Writing n_0 for the number of electrons per gram, equation (3) above can be expressed in two forms:

(*a*) for γ rays $\quad \mu/\rho = n \times {}_e\sigma/\rho = n_0 \times {}_e\sigma \quad$ (5)

since the term in λ^3 is negligibly small.

(*b*) for X-ray wavelengths

$$\mu/n = \mu/\rho n_0 = {}_e\sigma + 2{\cdot}64 \times 10^{-26}\,\bar{Z}^{2\cdot 94}\lambda_3 \quad (6)$$

Hence a comparison of γ-ray absorption in substances of known and unknown composition offers a method of determining n_0 for the latter. Similarly, if X rays of medium wavelength are used the values μ/ρ (measured)$/n_0$ (calculated), for substances of known composition, follow a linear function of $\bar{Z}^{2\cdot 94}$, and give a standard by which the experimental value of μ/n for an unknown substance can be used to determine its effective atomic number.

DETERMINATION OF ELECTRON DENSITY

The presentation will be simplified if the measurements of n_0, the number of electrons per gram, are first described, although the variations in n_0 are in fact not large, and the main characteristics of the materials are deduced from the X-ray measurements of the next section. The materials under test were contained in a rectangular glass cell (6 cm. × 4 cm. × 6 cm. deep) with a well-fitting lid which carried a compact source of 110 mg. of radium with a minimum filtration of 0·5 mm. Pt. A spherical "Aerion" condenser-chamber could be located in a close-fitting wax tube immediately below the glass cell; the radium-chamber distance was approximately 7 cm., and exposures of 7 or 8 minutes were necessary. The potentials were measured partly as differences on a Weston voltmeter and partly on a Lindemann electrometer, so arranged that 3 scale divisions corresponded to 1 per cent. of the total voltage to be measured.[7] Two independent measurements of μ/ρ were usually made for each material, with the cell filled to depths between 4 and 5 cm.; the mass per unit area for each case being determined by weighing. The absorption in the filled cell amounted to some 15 per cent., so that although the potentials measured were consistent to less than 0·5 per cent., the accuracy in the final value of μ/ρ was of the order of 3 per cent.

A number of materials of definite composition was first examined, and the measured mass absorption coefficients are compared with the calculated

values of n_0 in Table II. The ratio $\mu/\rho n_0$ in the last column should give the value ${}_e\sigma$ if total absorption were measured. The experimental arrangement, however, was such that almost all the scattered radiation reached the condenser chamber, with the result that the measured absorption approximated more nearly to ${}_e\sigma - {}_e\sigma_s$, *i.e.*, to ${}_e\sigma_a$. The mean value $11{\cdot}_1 \times 10^{-26}$ in Table II does, in fact, approach the theoretical value of $9{\cdot}7 \times 10^{-26}$ for ${}_e\sigma_a$ at a wavelength 0·015 Å.

TABLE II

Material	$\frac{\mu}{\rho}$ (measured)	n_0 (calculated)	$\mu/\rho n_0$
H_2O	$37{\cdot}0 \times 10^{-3}$	$3{\cdot}36 \times 10^{23}$/gm.	$11{\cdot}0 \times 10^{-26}$
$NaHCO_3$	34·1	3·03	11·3
C_6H_6	35·6	3·26	10·9
C_2H_5OH	37·5	3·42	11·0
C	34·5	3·03	11·8
NaCl	34·2	2·90	10·6
12% NaCl in H_2O	35·2	3·31	11·4
Mean value and average error for $\mu/\rho n_0 = 11{\cdot}1 \pm 0{\cdot}3 \times 10^{-26}$			

TABLE III

Material	$\frac{\mu}{\rho}$ (measured)	$n_0 = \frac{\mu}{\rho}\Big/ 11{\cdot}_1 \times 10^{-26}$
Paraffin wax	$40{\cdot}3 \times 10^{-3}$	$3{\cdot}63 \times 10^{23}$/gm.
Mixed wax (50% paraffin, 50% beeswax) ..	38·9	3·50
Mixed powder (60% rice, 40% $NaHCO_3$) ..	36·1	3·25
Pressdwood A	35·0	3·15
,, D	35·7	3·22
Pine	35·0	3·15
Oak	34·9	3·14
Sycamore	36·3	3·27
Mean value for woods $= 3{\cdot}2 \times 10^{23}$/gm.		

Table III gives the results for some materials of unknown composition and lists, in the third column, the values of n_0 deduced from the measured μ/ρ and the experimental figure of $11{\cdot}1 \times 10^{-26}$ for $\mu/\rho n_0$ obtained in Table II. It will be seen that the values of n_0 for the waxes are relatively high compared with water; they can be compared with the figure $3{\cdot}48 \times 10^{23}$ calculated for the paraffin $C_{16}H_{34}$. The value for the rice-sodium bicarbonate mixture is fairly close to that for water; the calculated value, assuming a starch formula, $(C_6H_{10}O_5)n$ would be $3{\cdot}14 \times 10^{23}$. All the values for various woods, including the pressdwoods, lie below that for water, and for them an average of $3{\cdot}2 \times 10^{23}$ can be regarded as a reasonable approximation.

Determination of Effective Atomic Number

Absorption curves were determined for a number of substances of both known and unknown composition using X rays generated at 60 kV (pulsating) and filtered with 1·2 mm. Al. The H.V.L. was 1·84 mm. Al and corresponded to an average wavelength of approximately 0·45 Å. The average wavelength deduced in a similar manner from the H.V.L. in carbon was found to be 0·46 Å. Scattered radiation could in this case be excluded, and constant and reproducible results were obtained from day to day, using either a Hammer integrating meter or a Siemens dosage-rate meter. The absorption was measured in terms of the weight per unit area of the material which, in the case of liquids and powders, was contained in a cylindrical glass cell. A careful determination of the H.V.L. in gm./sq. cm. was made for each material and the mass absorption coefficient deduced from the relation: $\mu/\rho = 0{\cdot}693$/H.V.L. in gm./sq. cm. This was thought to be the best course to adopt in view of the considerably heterogeneous radiation employed. Materials of known composition were used to give the calibration graph shown in Fig. 7, in which values of μ/ρ (measured)$/n_0$ (calculated) are plotted against calculated values of $\bar{Z}^{2{\cdot}94}$. The average wavelength calculated by means of equation (6) from the slope of the experimental curve in Fig. 7 is 0·43 Å. The difference between this value and those stated

above is probably due to the method employed to determine μ/ρ. Table IV gives the list of materials of indeterminate composition which have been studied; in it the values of $\mu/\rho n_0$ are experimental, based on measured H.V.L. values and on n_0 deduced from the γ ray experiments reported above. The experimental values of $\mu/\rho n_0$ are referred to the calibration curve in Fig. 7 to obtain an experimental figure for $\overline{Z}$, which is given in column 5. The bulk densities and resulting electron densities are then tabulated in columns 6 and 7.

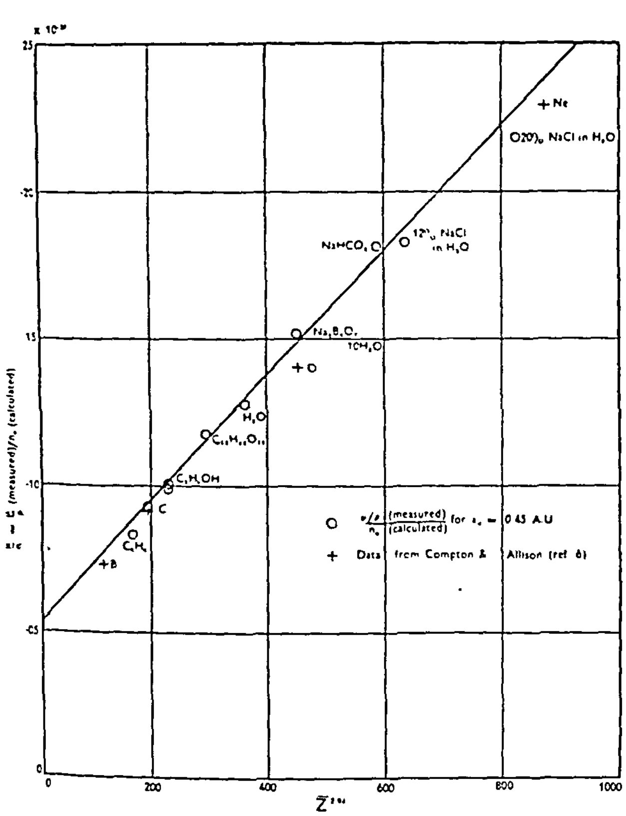


FIG. 7.

The effective atomic-numbers deduced for the natural woods do not vary greatly and, as might be expected from their general composition, lie somewhat below 7·42, the value for water. The sample of white cardboard tested has a value of $\overline{Z}$ considerably greater than 7·42. The value for paraffin wax is less than the theoretical figure of 5·41 for the paraffin $C_{16}H_{34}$; this is due in part to the uncertainty in n_0, which appears to be rather too high, and in part to the fact that the calibration curve in Fig. 7 is less accurate at low values of $\overline{Z}$. The addition of beeswax does produce an increase in $\overline{Z}$, but it is clear that any wax mixture must inevitably fall short of the value for water. The first three samples of pressdwood give values of $\overline{Z}$ approximately in the same range as the natural woods; their bulk densities are greater than unity, but their resulting electron densities are almost the same as for water. The fourth pressdwood "D" was one which had been rejected as unsuitable because of its low bulk density; its mass absorption coefficient at 0·45 Å is, however, twice as great as those for the other samples, and its effective atomic number is about 9·6. This unexpectedly high value is probably due to the bonding material; the texture of this pressdwood was quite different from that of the others, being almost devoid of any fibre or grain.

Using the experimental values of n and $\overline{Z}$ the linear absorption coefficients of the four pressdwoods were calculated and compared with water values as in the first part of the paper, and the resulting relative absorption curves are shown in Fig. 8. The pressdwoods A, B and C, agree reasonably well with water up to a wavelength of 0·25 Å, but for longer wavelengths their absorption falls well below that of water. They hardly appear satisfactory for the medium or low voltage therapy regions. The pressdwood "D" is, of course, well below water for short wavelengths, but its high $\overline{Z}$ value soon makes

TABLE IV

Material	H.V.L. (gm./sq.cm.)	n_0 (measured)	$\mu/\rho n_0$	$\overline{Z}$	ρ gm./c.c.	$n = \rho n_0$
Oak	1·88	3·2 × 10^{23}/gm.	0·115 × 10^{-23}	6·92	0·69	2·21 × 10^{23}/c.c.
Sycamore	1·87	,,	0·116	6·96	0·66	2·11
Pine	1·97	,,	0·110	6·72	0·41	1·31
Canary	1·91	,,	0·113	6·84	0·34	1·09
Spruce	1·94	,,	0·112	6·80	0·35	1·12
Teak	1·86	,,	0·116	6·96	0·63	2·00
Cardboard ..	1·50	,,	0·144	7·86	0·83	2·66
Paraffin wax* ..	2·48	3·63	0·077	5·02	0·89	3·23
Mixed wax* ..	2·40	3·50	0·083	5·38	0·91	3·19
Mixed powder* ..	1·50	3·25	0·142	7·79	1·08	3·50
Pressdwood A ..	2·08	3·2	0·104	6·48	1·06	3·39
,, B ..	2·02	,,	0·107	6·60	1·09	3·49
,, C ..	1·86	,,	0·116	6·96	1·04	3·33
,, D ..	1·00	,,	0·217	9·62	0·86	2·75

* Compositions as in Table III.

up the deficiency at longer wavelengths; at 0·25 Å the absorption is approximately equal to that for water and beyond this greatly exceeds it. Fig. 9 compares the measured transmission through the pressdwood "D" and water, and shows the

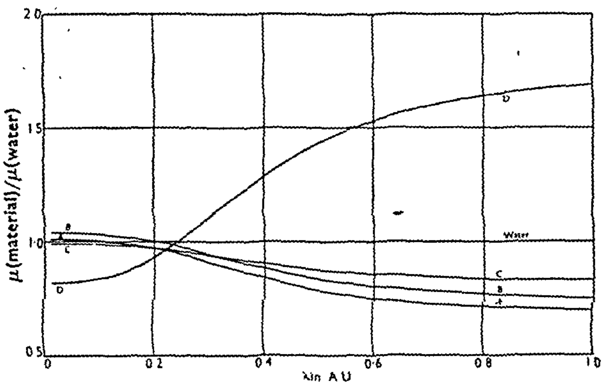


FIG. 8.

divergence from water, in opposite senses, for γ rays and for long wavelength X rays. At the intermediate wavelength 0·23 Å the transmission in the pressdwood is nearly the same as in water, but exact coincidence with the water curve would appear to be at a somewhat shorter wavelength than is indicated in the calculated curve in Fig. 8.

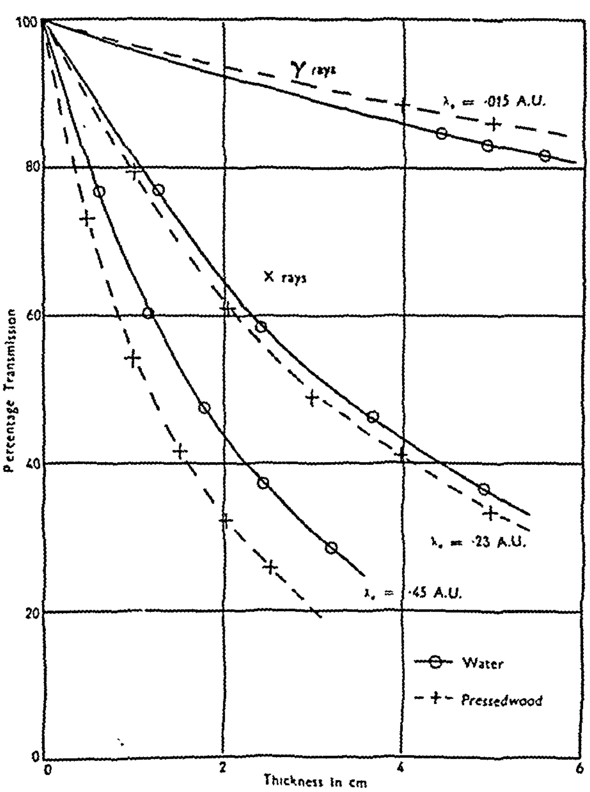


FIG. 9.

CONCLUSION

Both the experiments and theoretical considerations reported above show that care is necessary in selecting a material for the purpose of depth dose measurements. In spite of the difficulties of using a liquid, water appears to be the most satisfactory medium; its atomic and electronic properties are almost exactly the same as those for tissue of average composition, and it is available in a chemically pure state having a standard density. Much less can be claimed for the other materials investigated. Rice may be deficient in electron density as well as in effective atomic number; some pressdwoods may agree reasonably well with water up to wavelengths of about 0·2 Å, since in this region a little excess electron density may compensate for the lower atomic numbers of most woods. Both pressdwoods and waxes, however, appear unsafe for use at wavelengths greater than 0·2 Å, particularly in the low voltage therapy region. In view of the complex nature of absorption and scatter phenomena in an extended medium, a quantitative and exact correlation between depth dose measurements in different media cannot be made. It seems essential, therefore, that close agreement of electronic and average atomic properties with some standard such as water should be sought before using any material for the purpose of an extended investigation.

Similar experimental methods to those described are being applied to the determination of electronic density and effective atomic number of various types of tissue, bone and biologically related substances. By using more homogeneous X rays a greater accuracy in the determination of effective atomic number is aimed at, and it is hoped that the data so obtained will help in a closer study of true energy absorption in various media.

ACKNOWLEDGMENTS

I am greatly indebted to Professor W. V. Mayneord both for the experimental facilities he put at my disposal for testing the powder mixtures and also for his continued and helpful interest in the whole investigation. My thanks are also due to Mr. L. F. Lamerton for his assistance with part of the experimental work, and to Dr. C. W. Wilson, Mr. W. J. Meredith, and Mr. N. Robinson, who kindly supplied me with samples of pressdwood.

SUMMARY

The suitability of various materials, commonly used for depth dose measurement, has been tested by comparing their electron densities and effective atomic numbers with those of water. A powder mixture has been prescribed and tested which is satisfactory as a filling medium for "bolus" bags and for depth dose work in hollow anatomical models. Experimental methods for determining both the electron density and effective atomic number of light substances have been developed and have enabled similar critical tests to be applied to substances of indefinite composition such as mixed waxes and pressdwoods.

MUSEUM PAGE:
CALCIFICATION IN THE SUPRA-PITUITARY REGION

Contributed by E. Rohan Williams

-sellar Epidermoid Tumour. (Rathke ouch Tumour.) Fig. 1.

THE lateral radiograph of this child's skull shows both general and localising signs of a considerable intra-cranial "space-filling lesion." The general signs are: (i) appreciable separation of the sutural serrations; this may even be appreciated clearly in the tangential projection of the inter-parietal suture; and (ii) marked general impressions on the inner table of the vault bones of the cerebral convolutions (beaten-copper skull). The localising signs are: (i) flocculent calcific deposits situated above and mainly anterior to the pituitary fossa, and (ii) general enlargement of the fossa in all directions with elongation and thinning of the posterior clinoid processes. We are thus presented with a large space-filling lesion showing much calcification above the sella and either entering into, or arising from, the sella. The appearances are characteristic of a large *supra (and intra)-sellar epidermoid tumour (craniopharyngeioma)*. There was operative and histological confirmation.

B. Intra-cranial Aneurysm. Figs. 2, 3, and 4.

In both the lateral and the postero-anterior radiographs an extensive curvilinear calcium deposit is seen above the sella and lying mainly to the right of the mid-line. A full half-circle of calcification is seen in both views, more sharply in the postero-anterior radiograph. The only bone change is an erosion of the right anterior clinoid process. The sella turcica is not enlarged.

The differential diagnosis lies between a supra-sellar epidermoid tumour and a large aneurysm of the right carotid or one of its major branches.

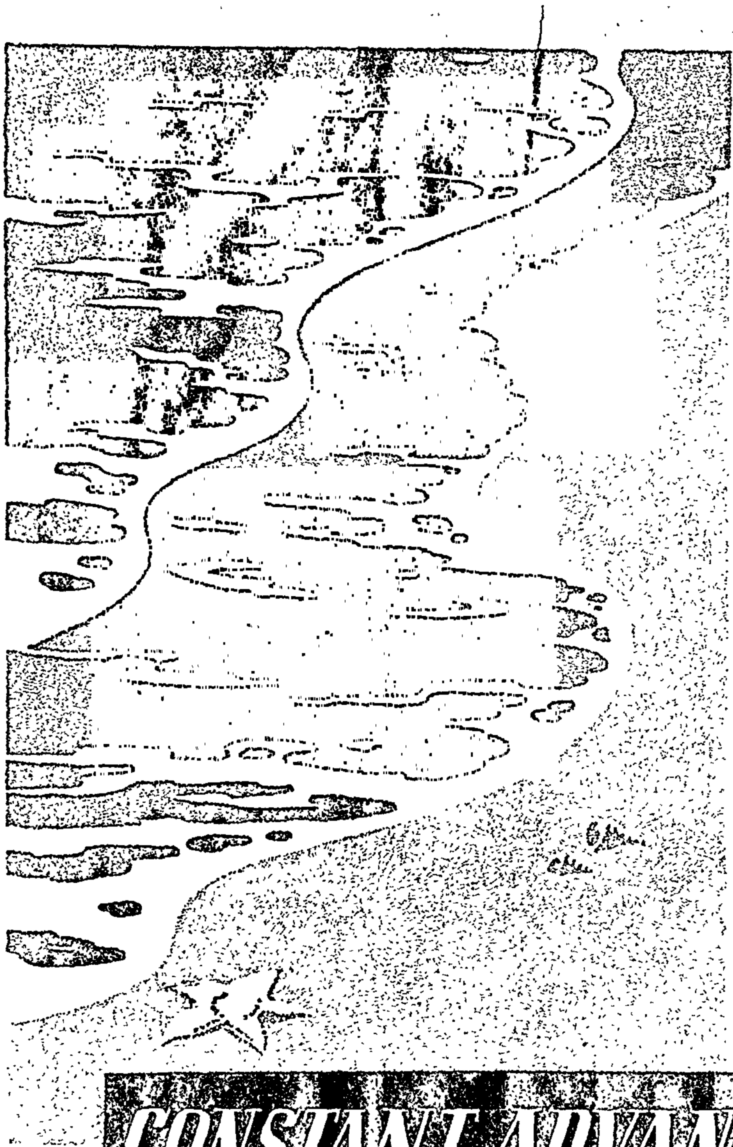
The type of calcification markedly favours the aneurysm, and this was later supported by the appearances on carotid arteriography.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.



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